

Assessment of Water Quality in Cilutung Watershed

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Abstract. Water is very valuable resources that provide people and other living things. Besides the need for water for drinking, water resources play an important role in such as livestock, fisheries, water for irrigation and water recreation. However, water quality of the rivers may degrade due to the variation of land use as human activities increase. Cilutung watershed is dominated by the agricultural land use which in many studies shows that agricultural land use has a great impact on river deterioration. It does not affect only the physicochemical of water, the excessive amount of nutrient may harm the biotic ecosystem. The purpose of this study was assessing water quality of the rivers in Cilutung Watershed and the contributing factors using physicochemical and biological parameters. According to ANOVA and PPM calculations, water quality was affected by land use spatially and river discharge temporally. The overall results showed that the rivers were categorized as slightly polluted referring to WQI, BMWP, and Saprobic Index. In general, all water quality parameters measured in Cilutung watershed met water quality standard Class III as stipulated in Indonesia Government Regulation No. 82/2001. Therefore, water sources were still acceptable for fisheries, animal husbandry, and water for irrigation.

Keywords: **Water Quality ; Land Use ; BMWP-ASPT ; Saprobic Index ; WQI.**

1 Introduction

Rivers play an important role in maintaining the balance of the ecosystem and also the main source of water for the living things that live in the surrounding area. It is one of the most important compounds that profoundly influence life [1]. Nonetheless, rivers are very vulnerable to land use change and tremendous exploitation [2,3]. The availability and quality of water either surface or ground, have been deteriorated due to some important factors like increasing population, industrialization, urbanization etc [4]. It is, therefore, water quality of the rivers should be assessed.

River water quality monitoring is very important for rivers affected in urban area [5]. With the rapid economic and social development in recent decades, non-point source pollution to the environment from livestock, industries and rural domestic sewage to our living space [6]. Indiscriminate use of chemical fertilizers and pesticides in agriculture are also causing heavy and varied pollution in aquatic environment leading to deterioration of water quality [1].

In many regions, water quality of the rivers has been assessed by monitoring several parameters periodically. In order to obtain the accurate trends, water quality data need to be measured frequently and over long periods during dry and rainy season especially for tropic region. However, this can be time consuming and expensive, especially if numerous parameters are measured [7].

According to Indonesia Government Regulation No. 82/2001 regarding the Management of Water Quality

and Water Pollution Control, water quality parameters can be divided into 3 major groups namely physical, chemical, and biological. These parameters are widely known for river health monitoring in Indonesia. Particularly, the biological communities that are exposed to pollutants act as integrators of the multiple present and past environmental effects [8].

The purpose of this study was to assess the water quality of several selected rivers in Cilutung Watershed using WQI, BMWP, and Saprobic Index. Furthermore, this study aimed to classify the rivers according to the level of pollution and examines water quality standards according to Indonesia regulation. To analyze the water quality of the rivers spatially and temporally, land use and river discharge were being calculated in statistical analysis to provide the correlation.

2 Materials and Methods

2.1. Study Area

Cilutung Watershed is located at the boundary of Majalengka District and Sumedang District, West Java, Indonesia. The total coverage of Cilutung Watershed is 636.600 hectares and consist of several Sub-Watershed. However, in this study only 3 Sub-Watershed is selected based on the variation in land use. Land use data is obtained from the National Development Planning Agency Republic of Indonesia for West Java Region.

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Cideres Sub-Watershed is the largest Sub-Watershed among others study area. Total coverage of Cideres Sub-Watershed is 8.162 hectares. Cideres Sub-Watershed consists of 6 types of land use i.e. settlement, forest, shrub, rice field, plantation and cultivated area. Rice field is the major land use which covers 30% of Cideres Sub-Watershed or approximately 2.452 hectares. Meanwhile, forest land use only can be found in this Sub-Watershed. Cideres river is the major river in Cideres Sub-Watershed. Cideres river upstream is located in Argapura Sub-District and river downstream is located in Panyingkiran Sub-District. Cideres river downstream that is located at Bantrangsana Village was selected as the first sampling site.

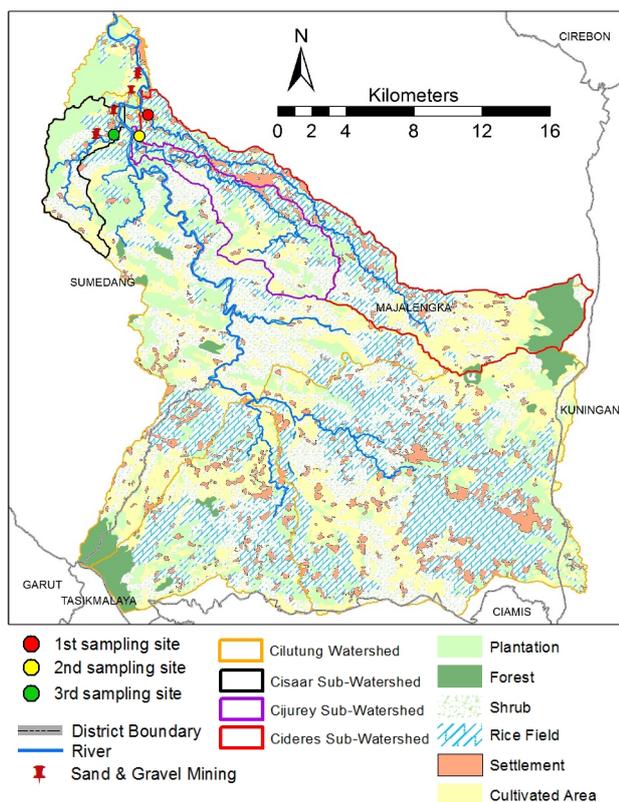


Fig. 1. Study Area

Total coverage of Cijurey Sub-Watershed is 3937 hectares. This Sub-Watershed consists of 5 types of land use i.e. settlement, rice field, shrub, plantation, and cultivated area. Rice field is the major land use which covers 29% of Cijurey Sub-Watershed, meanwhile settlement is the minor land use which covers around 7% only. Cijurey river is the major river in Cijurey Sub-Watershed. Second sampling site was selected at Cijurey river downstream, precisely located at Cijurey Village, Panyingkiran Sub-District, Majalengka District.

Cisaar Sub-Watershed is the smallest Sub-Watershed with the total coverage approximately 2.288 hectares. This Sub-Watershed is located at Sumedang District. Unlike others study area, Cisaar Sub-Watershed is dominated by plantation land use which covers 37% of Cisaar Sub-Watershed. Cisaar river is the major river in Cisaar Sub-Watershed and third sampling site was selected at the downstream of Cisaar river that is located

at Darmawangi Village, Tomo Sub-District, Sumedang District. Nevertheless, what makes Cisaar Sub-Watershed different is the existence of sand and gravel mining practices.

2.2 Sampling Methods

Field sampling was carried out at 3 sampling sites. All sampling sites were located at the downstream of the river. This study was limited to 6 days of field observation. Water quality, macroinvertebrates, and plankton sample were collected from 6th April to 11th April 2018.

Water quality sample measurements were carried out twice a day (9 AM and 2 PM). Water quality samples were measured in Hydrological Laboratory and in situ. Macroinvertebrates sample were caught randomly from each substrate i.e. mud, clay, and riparian vegetation. Plankton samples were caught purposely from left and right banks of the river. Biological samples preserved with formaldehyde henceforth being identified using microscope.

2.3 Water Quality Index

WQI was developed by Horton (1965) [9] in US by choosing 10 most commonly used water quality parameters i.e. dissolved oxygen (DO), fecal coliforms, pH, alkalinity, chloride etc. and has been widely applied and accepted in European, African and Asian countries [4]. As times goes by, many modification has been considered for WQI concepts. In this study the WQI concept from National Sanitation Foundation was applied to measure. NSF WQI is using nine parameters i.e. turbidity, fecal coliform, pH, temperature, biochemical on demand (BOD), dissolved oxygen, total phosphates, nitrate and total solids. However, this study was limited to six parameters. The mathematical expression for NSF WQI is given by

$$WQI = \sum_{i=1}^n Q_i W_i \dots\dots\dots (1)$$

Where,

Q_i = sub-index for its water quality parameter
 W_i = weight associated with its water quality parameter
 n = number of water quality parameters
 for NSF WQI methods, the rating of water quality have been defined by using following [4] :

Table 1. Water Quality Rating defined by NSF WQI

WQI Value	Rating of Water Quality
91 – 100	Excellent
71 – 90	Good
51 – 70	Medium
26 – 50	Bad
0 – 25	Very bad

2.4 BMWP-ASPT Index

All macroinvertebrates samples were identified to family level. After being identified, macroinvertebrates were calculated using BMWP-ASPT. BMWP gives vary tolerance score for each family level of macroinvertebrate based on their ability to survive from certain environmental conditions. The range score is 1 to 10, the higher score indicates the most sensitive macroinvertebrates and vice versa, despite not all macroinvertebrates found in water bodies are included in BMWP scoring.

According to ASPT calculation, level of pollutions are classified into 4 categories namely heavily polluted (< 4), moderately polluted (4 – 5), slightly polluted (5 – 6) and not polluted (> 6). The overall BMWP-ASPT calculation is shown below :

$$ASPT = \frac{\sum A_i}{B} \dots\dots\dots (2)$$

Where,

A = BMWP score family-i

B = total family macroinvertebrates found

2.5 Saprobic Index

The saprobic degree is a measure for the phase in which the process of conversion of biologically decomposable substances has taken place in surface water. Determination of these phases which merge imperceptibly into one another can be made by examining the population of living organisms present in the water, since experience has shown that some organisms are able to survive in a particular phase of the conversion process [10].

The types of phytoplankton found tabulated in the table and are grouped in the same classes. In addition to tabulating type also noted the average number of specimens per type of class that will be used to calculate the coefficient of saprobic phytoplankton as one of the parameters determining the level of pollution [11], especially organic contamination using the formula Dresscher and Van der Mark 1976, as follows :

$$X = \frac{(C+3D-B-3A)}{(A+B+C+D)} \dots\dots\dots (3)$$

Where,

A = Phytoplankton classes that are found belong to class Polysaprobic.

B = Phytoplankton discovered class into α-mesosaprobic class.

C = Phytoplankton are found into β-mesosaprobic class.

D = Phytoplankton classes that are found belong to class Olygosaprobic.

The saprobic indexes of the used taxa, expressing their tolerance limits to organic pollution, were established based upon the frequency of their occurrence (percentage of occurrence) in the different saprobic

levels of water in the habitats where they were found [12].

This method has the advantage that can accurate species determination, which is otherwise necessary for a biological analysis is not compulsory. Classification of forms into the groups and counting the forms per group is sufficient [10]. Table 2 shows the various saprobic quotients are compared with the degree of pollution and the saprobic phases.

Table 2. Various Saprobic Quotients Compared with the Degree of Pollution and Saprobic Phases

Load	Pollution	Saprobic Phases	Saprobic Quotient
Many organic substances	Very severe	Polysaprobic poly/α-meso saprobic	-3 / -2 -2 / -1,5
	Considerable	α-meso / polysaprobic α-mesosaprobic	-1,5 / -1 -1 / -0,5
Organic and inorganic substances	Moderate	α/β mesosaprobic β/α mesosaprobic	-0,5 / 0 0 / +0,5
	Slight	β mesosaprobic β meso / oligosaprobic	+0,5 / +1 +1 / +1,5
Few organic and inorganic substances	Very slight	Oligo / β mesosaprobic Oligosaprobic	+1,5 / +2 +2 / +3

3 Results and Discussion

3.1. Land Use

Cideres Sub-Watershed, Cijurey Sub-Watershed, and Cisaar Sub-Watershed have different land use composition. But overall, the study areas are dominated by agriculture land use. The composition of land use in the study area can be seen on pie chart below.

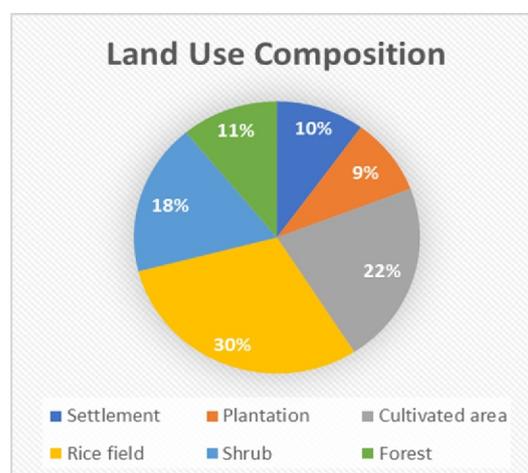


Fig. 2. Composition of Cilutung Watershed Land Use

Geographic Information System provided a watershed-scale of existing land use. Cilutung watershed is dominated by agricultural land use as informed above. In many parts of the world increase of agricultural production heavily depend on intensive agricultural practices which are having negative impact on the environment [13]. Previous study claimed that the nutrients associated with fertilizer (nitrogen and phosphorus containing compounds) and urban waste (nitrogenous compounds and phosphate) showed relationships with land use and biotic indices [14] although land use is not the only causes of river deterioration. River is a dynamic ecosystem, influenced by various activities in the river bank [15].

3.2. Statistical Analysis

To analyze the correlation between water quality and land use, One Way Analysis of Variance (ANOVA) calculation was obtained using SPSS. The result showed that F value from 9 physicochemical water quality parameters were greater than F statistic (3,28). Thereby, the null hypothesis can be rejected in support of the conclusion that the water quality really does vary significantly based on many factors. One of the factors that can affect river water quality is the composition of land use in each Sub-Watershed. River water quality can be caused by many factors such as discharge, rainfall, land use, geology, soil, and many more. But this study was also trying to find a correlation between land use and river discharge to water quality spatially and temporally.

Table 4. ANOVA calculation

Parameters	Average Parameters			F stat	F value
	Cideres	Cijurey	Cisaar		
TDS (mg/L)	86,67	168,33	351,67	3,28	688,083
Conductivity (µmhos/cm)	180	342,50	699,17	3,28	659,976
TSS (mg/L)	58	29	150	3,28	23,110
Turbidity (NTU)	112,79	14,78	255,08	3,28	17,013
Temperature (°C)	28,79	29,98	30,98	3,28	9,728
Nitrate (mg/L)	18,63	15,99	13,06	3,28	3,582
Phosphate (mg/L)	0,15	0,11	0,10	3,28	7,828
DO (mg/L)	10,77	10,58	11,59	3,28	3,857
pH	7,46	7,54	7,70	3,28	7,789

Water quality was affected by river discharge. Based on the calculation of PPM between discharge and water quality parameters, several parameters had positive correlation such as TSS, DO, and turbidity. However, discharge had a negative correlation with water quality parameters such as TDS, nitrate,

phosphate, pH, temperature, and DHL. River discharge had a strong correlation with TDS, TSS, turbidity, DHL, and nitrate parameters because it had r value greater than 0.5.

Table 5. PPM Calculation

r value	Study Area		
	Ciders	Cijurey	Cisaar
TDS	-0,86	-0,92	-0,75
TSS	0,9	0,81	0,9
Turbidity	0,98	0,87	0,94
Conductivity	-0,81	-0,92	-0,85
Temperature	-0,12	-0,22	-0,21
Nitrate	-0,84	-0,92	-0,66
Phosphate	-0,01	-0,21	-0,16
DO	0,15	0,96	0,35
pH	-0,25	-0,43	-0,5

Although statistical analysis as adopted in several previous studies are an affective approach for identifying significant explanatory variables (e.g. land use) affecting water quality, they can not quantitatively estimate contributions of respective land use on the water quality because they are only based on the existence of statistical significance in the data [16]. However, previous study [17] concluded the statistical analysis revealed that spatial variations in river water quality were related to numerous anthropogenic and natural factors. Urban land use was found to be the most important explanatory variable for BOD₅, COD_{Mn}, TN, DN, NH₄⁺-N, NO₃⁻-N, DO, pH and TP.

3.3. Water Quality Classification

Three methods were used to assess water quality of Cideres River, Cijurey River, and Cisaar River. The water quality parameters were separated into two groups, physicochemical parameters and biological parameter. Six physicochemical parameters such as nitrate, temperature, DO, turbidity, TSS, and pH were calculated using WQI method. The WQI result obtained below.

Table 4. Water Quality Based on NSFQWI

Parameters	Score		
	Ciders	Cijurey	Cisaar
DO	50	50	50
pH	88	88	88
Temperature	89	85	85
Nitrate	39	43	46
Turbidity	5	69	5
TSS	87	84	79
Final Score	59	67	59
WQI	Medium	Medium	Medium

WQI calculation showed that Cideres River, Cijurey River, and Cisaar River were categorized as

medium/slightly polluted. Hereafter, the biological parameter which included the presence of macroinvertebrates and plankton were examined using BMWP-ASPT and Saprobic Index.

Many macroinvertebrates live most of their lives in freshwaters, and their diversity, omnipresence, and sensitivity to environmental stressors, including organic and inorganic pollutants, can make them effective estimators of overall, integrated water quality [18]. The findings of the present study [13] showed that lowered macroinvertebrate family richness and abundance values reported in agricultural sites may have attributed to the degraded habitat quality. Aquatic insect communities are used as surrogates: their observed responses give early warning of damaging changes [19].

Not all macroinvertebrate families found in the waters are included in the BMWP index. In this study 24 families and 2 phylums (Arthropods and Mollusca) of macroinvertebrate were identified from 3 sampling sites. Arthropods were the most commonly found. BMWP index considers only the presence of certain families. BMWP Index also showed that these rivers were categorized as slightly polluted.

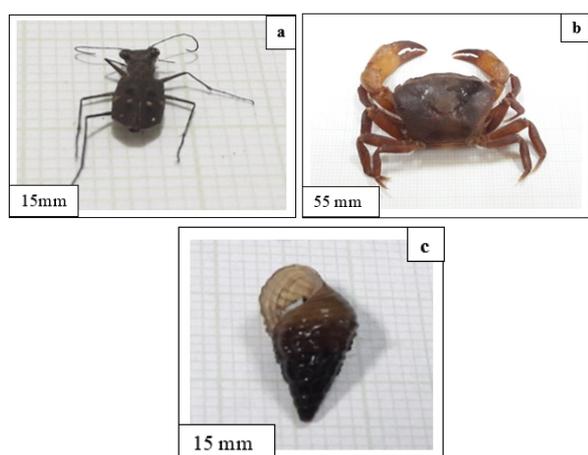


Fig. 3. Samples of macroinvertebrates that found in all sites, Cincidelidae (a), Parathelphusidae (b), Thiaridae (c)

BMWP index groups macroinvertebrate families into 10 levels based on their sensitivity to environmental changes. The higher the BMWP score on an organism, the higher the sensitivity to changes in environmental conditions. Conversely, the lower the BMPW score, the lower the level of sensitivity to changes in environmental conditions.

Table 6. Water Quality Based on BMWP-ASPT

River	BMWP Score	Pollution
Cideres	5	Slight
Cijurey	5,8	Slight
Cisaar	5,7	Slight

Plankton is important members of the aquatic food web. The plankton includes phytoplankton or algae (microscopic plants) and zooplankton (tiny shrimp-like

animals that eat algae). Small microscopic shrimp-like crustaceans called zooplankton eat the phytoplankton. In turn, the zooplanktons are extremely important food for young fish [1].

The species are listed according to their abundance in the rivers as follows : *Chlorophytes*, *Crysophytes*, *Euglenophytes*, *Cyanophytes*, and *Charophytes*. According to Saprobic Index, Cideres River, Cijurey River, and Cisaar River were also categorized as medium/slightly polluted with β -Mesosaprobic Phase. Aqueous pollutants comprise a small amount of organic and inorganic compounds.

Table 7. Water Quality Based on Saprobic Index

River	Saprobic Index	Degree of Pollution	Saprobic Phase
Cideres	0,78	Medium	β -Mesosaprobic
Cijurey	0,89	Medium	β -Mesosaprobic
Cisaar	0,86	Medium	β -Mesosaprobic

Water pollutants entering water bodies are mostly suspected as a result of agricultural activity. This can be seen from the dominant use of agricultural land in the study area. Agriculture is one of the activities that can cause an algae explosion and impact on water quality degradation.

Excessive amount of phosphorus and nitrogen in water body resulting in rapid algae blooming [1]. The growth of algae leads to more death and decomposition. The process requires dissolved oxygen, resulting in lower levels of dissolved oxygen in the water. These conditions encourage the growth of anaerobic organisms in the water. This phenomenon is also known as eutrophication [20]. The existence of rice fields allows the abundance of nutrients in the river.

4 Conclusion

Water quality of the rivers in Cilutung watershed was a result of various human activity. Cideres River, Cijurey River, and Cisaar River water quality were spatially affected by concentrations of land use in Sub-Watershed. The result of ANOVA calculation showed that F value from 9 physicochemical water quality parameters was greater than F statistic (3,28). Thereby, the null hypothesis can be rejected in support of the conclusion that the water quality really does vary significantly based on many factors such as land use and river discharge. According to PPM calculation between discharge and water quality parameters, river water quality was also affected by river discharge temporally.

River water quality was thoroughly analyzed based on the calculation of WQI, BMWP-ASPT, and Saprobic Index. The result showed that Cideres River, Cijurey River, and Cisaar River were categorized as medium or slightly polluted river. According to saprobic index, the study area was classified to β -Mesosaprobic phase which means the pollutant comprises a small amount of organic and inorganic compounds.

In general, all water quality parameters measured in Cilutung watershed met water quality standard Class III referring to Indonesia Government Regulation No. 82/2001 regarding the Management of Water Quality and Water Pollution Control. Therefore, water sources were still acceptable for fisheries, animal husbandry, and water for irrigation.

Assessment of water quality in rivers that present hydrological discontinuities must combine different approaches in order to produce a correct diagnosis of the status of the running water system [21]. The wastewater from agricultural, residential, and industrial should be treated before being released into the river. Thereafter use of fertilizer needs to be carried out in more depth and further research. In addition, the method of analyzing the relationship between land use and water quality should be expanded.

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