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The characteristic of Natural Organic Matter (NOM) of water from Cikapundung River Pond

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Abstract. Natural organic matter (NOM) is an important parameter in drinking water due to its roles as one of main precursors of trihalomethanes (THMs). The characteristic of NOM might be influenced by land use of catchment area. The present study aims to analyse the correlation between various NOM parameters and THMs, and physical characteristics of raw water. The effect of land use around the catchment is also presented. The samples were taken from Cikapundung river pond, which is used by the water company of Bandung City as raw water sources for drinking water. Geographic Information System (GIS) was applied to distinguish anthropogenic and natural land use around the water catchment. The samples were categorised as unfiltered samples and filtered samples to measure dissolved material. Turbidity and conductivity were measured to obtain the physical characteristics of water. NOM parameters were as of TOC, DOC, COD, UV_{254} and UV_{355} . The turbidity and conductivity of water were 5-34.7 NTU and 132-306 $\mu\text{mhos/cm}$, respectively. COD was from 32 to 76.8 mg/L. TOC was between 4.22 and 6.92 mg/L. UV_{254} and UV_{355} ranged 0.15-0.38 cm^{-1} and 0.09-0.16 cm^{-1} , respectively. COD and conductivity correlated well in unfiltered ($r = 0.923$) and filtered sample ($r = 0.995$). In both unfiltered and filtered samples, UV_{254} were correlated with UV_{355} with r of 0.986 and 0.995 respectively. The results revealed that catchments area of the pond was possibly dominated by anthropogenic activities.

1. Introduction

Natural organic matter (NOM) is an important water quality parameter. NOM has been known as the main precursor of disinfection by products (DBPs) in chlorination process. USEPA [1] identified that the NOM is the major precursor of two out of three DBPs such as organic oxidation by product and halogenated organic by product. Jacangelo *et al* [2] found that NOM in the pretreated water may generate serious problems to treatment process of drinking water.

In chlorination process, the most popular DBPs is trihalomethanes (THMs). THMs are potentially considered as carcinogenic, mutagenic, and able to damage liver function [3]. The four THM species, including trichloromethane (TCM), and the brominated compounds such as bromodichloromethane (BDCM), dibromochloromethane (DBCM), and tribromomethane (TBM) are mostly found in disinfected water [3].

The heterogeneity of NOM is influenced by the location of water sources and land use of the catchment area [4-9]. Due to the heterogeneity of NOM, not all parameters of NOM are correlated with THMs. Previous studies suggested that chromophoric NOM parameters such as UV_{254} is correlated with THMs [10-15]. Other studies concluded that total organic carbon (TOC) and dissolved organic carbon



(DOC) correlated with THMs [16-18]. However, in Indonesia, chemical oxygen demand (COD) is the most common parameter to determine organic matter in raw or pretreated water quality. The problem arises since there is no strong correlation between COD and THMs.

Turbidity and conductivity are common physical parameters and relatively easy to be measured. Further, these parameters can be used as surrogate parameters, thus it is important to know the correlation between these parameters and NOM parameters. In Indonesia, the studies on correlation among NOM parameters and physical parameters is rare.

Cikapundung River has been the primary raw water sources of PDAM Tirtawening, a local water company in Bandung City. Although this river has been determined as a strategic area of the city, the condition of Cikapundung River has been severely polluted. The Environmental Protection Agency (EPA) of Bandung City accounted the water quality status by STORET method in the Cikapundung river and they found the river is polluted. Another important role of Cikapundung River is to provide raw water as many as 640 L/sec in water production region 2 of PDAM Tirtawening. One of the installations is the Mini Plant Dago Bengkok, which is used by the river pond to provide detention time for discrete particle to settle.

It is important to study the characteristic of NOM from river pond because they are so many installations in Indonesia, which use river pond as the main water source. It is believed that the pond can provide raw water better in quality but there is no sufficient information about the characteristic of NOM and physical characteristic of water at water pond. Furthermore, Water Company has been used chlorine in disinfection process. Chlorine is the most used chemical oxidant for drinking water disinfection in Indonesia.

This research is aimed to analyze the characteristic of physical parameters such as turbidity and conductivity, liability NOM such as COD, parameters of NOM which related to THMs (UV₂₅₄, TOC and DOC), and terrestrial NOM (UV₃₅₅). This study evaluated the correlation among those parameters on unfiltered and filtered samples from the selected river pond.

2. Material and Methods

2.1. Study area

The Cikapundung is important river since it has many functions, such as drinking water source, key drainage canal system, and recreation. The Cikapundung River has provided raw water for three main installations of PDAM Tirtawening Kota Bandung. The sampling location coordinate of Cikapundung Pond is S 06°51'33.1" & E 107°38.57'57.1". The pond provides 40 L/sec of raw water to be treated at mini plant and the treated water is distributed to North area of Bandung.

2.2. Geographic Information System (GIS) work

GIS were used to delineate the catchment area of the river pond and determine the natural area and anthropogenic areas which were affected by human activities in the catchment area of river pond. The shape file map was obtained from the Department of Spatial Planning and Human Settlement of West Java Province.

2.3. Water sample collection

The water sampling was conducted in 10 days at the outlet of river pond. The samples were divided into unfiltered and filtered sample. To determine dissolved NOM, the samples were filtered by Advantech membrane with diameter of 0.45 µm.

2.3.1. Physical characteristic measurements. The measurement method of these parameters were based on Standard Method and listed at Table 1.

Turbidity is an appearance of the optical properties that causes light to be scattered and absorbed rather than transmitted [19]. The measurement method of turbidity is by nephelometric method

according standard method 2130 B. Conductivity is a measure of the ability of an aqueous solution to carry an electric current [19]. The measurements of these parameters were carried out *in situ*.

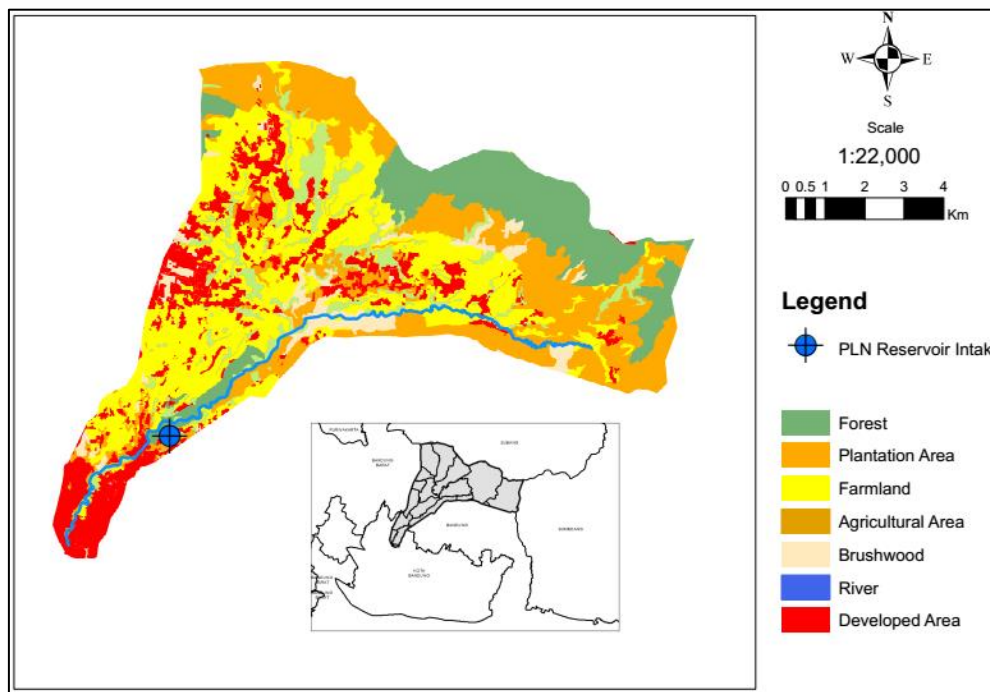


Figure 1. Catchment area of Upper Cikapundung.

Table 1. Method of measurements.

No	Parameter	Measurement method
1	Turbidity	Standard methods 2130 B
2	Electrical Conductivity	Standard methods 2510
3	COD	Standard methods 5220 D
4	DOC	Standard methods 3510 B
5	UV ₂₅₄	Standard methods 5910 B

2.3.2. NOM measurements. UV absorption is a useful surrogate parameters of organic contaminant in fresh water [19]. UV₂₅₄ measures the humic, lignin, tannin and various aromatic compound [19]. The origins of NOM influence THMs formation [15]. Some parameters such as UV₃₅₅ is described as the chromophoric NOM derived from terrestrial [20]. COD is a measurement of the oxygen required to oxidize chemically soluble and particulate organic matter in water [21].

Chromophoric NOM parameters such as UV₂₅₄ and UV₃₅₅ were measured by Spectrophotometer UV-VIS CAMSPEC M500. TOC and DOC were measured by TOC analyzer SIEVER Innovox 0545 and COD measurement used close reflux method.

2.4. Statistical analysis

Correlation is a statistical technique that indicates how strong pairs of NOM and physical parameters are related. The NOM parameters were: lability NOM (COD), chromophoric NOM (UV₂₅₄ and UV₃₅₅), and bulk organic carbon NOM (TOC and DOC). Meanwhile the physical parameters were turbidity and electrical conductivity. The data were analyzed statistically by SPSS 19.

3. Result and discussion

3.1. Land use pattern in catchment area of river pond

The river pond is part of Cikapundung River. Figure 2 illustrates the catchment area of river pond. Land use in the catchment area was grouped into two categories:

1. Forest is natural area (green), there were no significant human activities in this area,
2. Developed area (yellow), there were significant human activities in these areas. The land use in this area are: agricultural; farm; livestock; traditional market; and residential area.

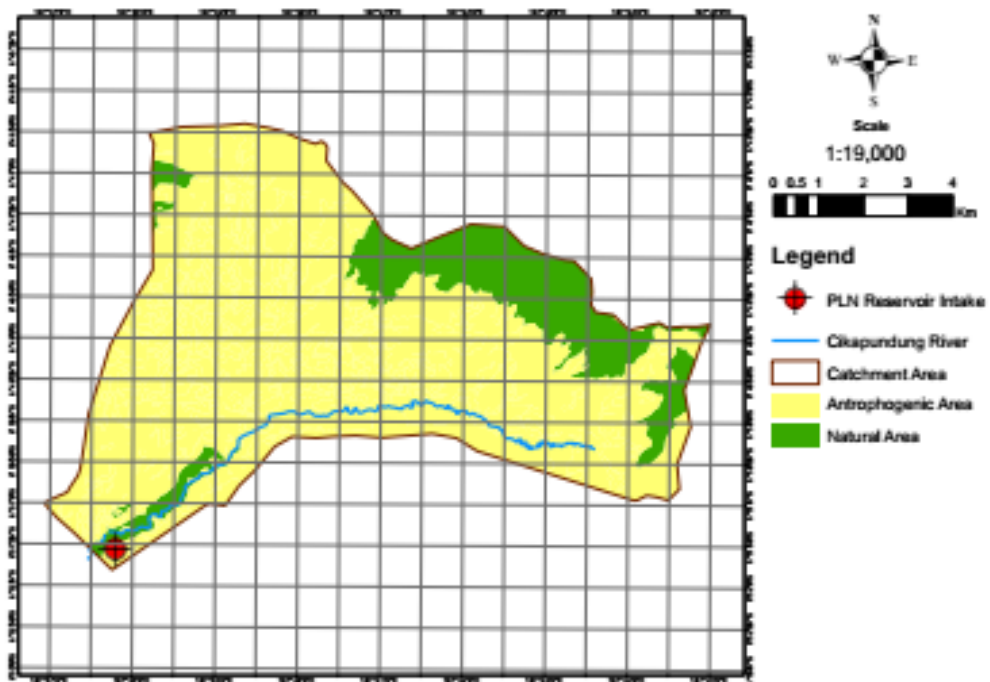


Figure 2. Land use pattern in catchment area of the intake.

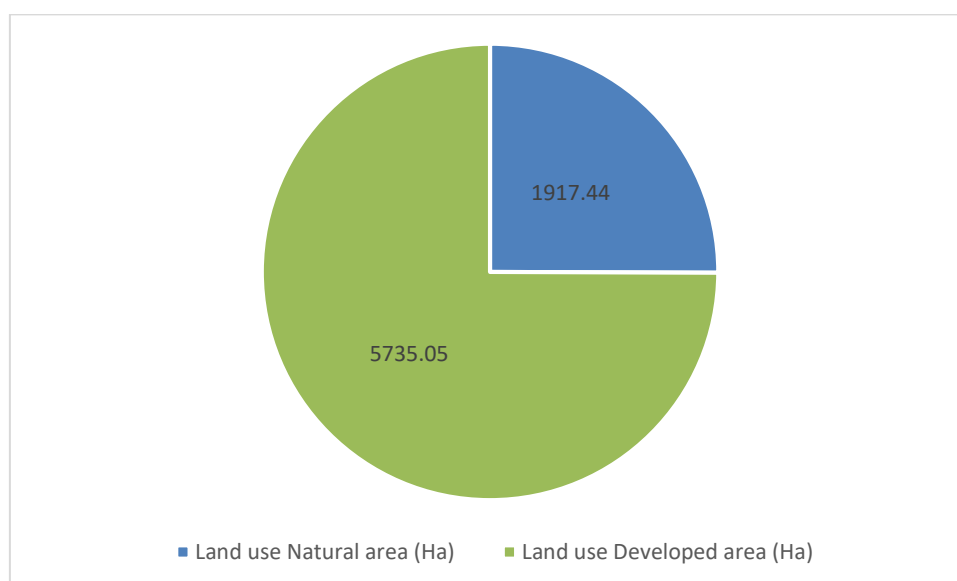


Figure 3. Natural and anthropogenic area in the catchment area of river pond.

Figure 3 shows, the catchment area of river pond was predominantly used for anthropogenic activities (75%). Meanwhile the natural area was only 25%. This condition affected the water quality of Cikapundung River. The human activities which affected the water quality in this catchment area are (PDAM Tirtawening, 2015):

- Some farming where livestock activities at the catchment area directly discharge the waste to the rivers,
- Domestic and non-domestic activities that discharge wastewater and solid waste directly to the river.

3.2. Physical and NOM characteristic

Table 2 summarizes the physical characteristic of filtered and unfiltered samples. In the unfiltered samples, the turbidity of samples ranged between 15.8 and 34.7 NTU. However, the turbidity decreased to 0.1-4.3 NTU in filtered samples, and it was suitable with standard of drinking water quality standard (<5 NTU). This condition happened because the turbidity of the water sample was dominated by suspended and colloid material, thus the turbidity of the sample decrease significantly after the sample was filtered. Furthermore, the sampling was done during rainy seasons which may increase the concentrations of suspended particles in the sample.

Table 2. Physical characteristic of the sample water from Cikapundung River Pond.

Sample	Turbidity (NTU)	Conductivity ($\mu\text{mhos/cm}$)
Unfiltered	15.8-34.7	132-306
Filtered	0.1-4.3	82-201

Electrical conductivity of water is an indicator of its salinity or total salt content [22]. The conductivity of sample ranged between 132 and 306 $\mu\text{mhos/cm}$. After the sample was filtered, it decreased by 37%, ranged between 82 and 201 $\mu\text{mhos/cm}$. The conductivity of the sample is predominantly caused by dissolved material. This was due to dissolved solid in the water conduct electrical current in the water [23]. Normally, in the surface water the conductivity decreased due to dilution with runoff water [24].

Table 3. Organic characteristic of the sample water.

Sample	COD (mg/L)	UV ₂₅₄ (cm^{-1})	UV ₃₅₅ (cm^{-1})	TOC (mg/L)
Filtered	32-76.8	0.15-0.38	0.09-0.21	4.22-6.92
Unfiltered	17-48	0.12-0.29	0.07-0.2	3.28-3.58

In Table 3, all COD values in unfiltered and filtered samples were above the maximum value of COD in stream standard (10 mg/L). These results show that more than half of lability NOM, measured as COD were dissolved. This was supported by Tommassen [23] which found COD comprise of particle suspended and dissolved solid in the water. This may indicate water pollution by organic compounds. GIS shows, the land use area of the catchment is dominated by anthropogenic activities. Direct discharge from anthropogenic activities affected this condition.

TOC were between 4.22 and 6.92 mg/L and the DOC were between 3.28 and 3.58 mg/L. The concentration of particulate organic carbon (POC) in the sample were between 0.94-3.34 mg/L, these value was lower than DOC. TOC consist of DOC and POC [5,25]. Niu *et al* [26] reported, DOC in Yuqiao Reservoir were between 2.96-3.54 mg/L and classified as medium. Meanwhile Zhao *et al* [14] reported the DOC from polluted water was only 2.02 mg/L, slightly lower from river pond sample.

Organic aromatic of the sample as UV_{254} was 0.15-0.38 cm^{-1} before filtered and decrease 23% after filtering. This organic value is considerably high. Hua *et al* [27] reported that in raw water polluted by agricultural activities, the UV_{254} was 0,313 cm^{-1} . Meanwhile, Wang *et al* [28] reported that the value of UV_{254} from filtered water of Songhua river was only 0.063 cm^{-1} . GIS shows that the developed area in the catchment of river pond were not only agricultural but also residential area, traditional market, livestock and farm. This fact shows the sample dominated by organic aromatic both in filtered and unfiltered water.

Organic from terrestrial as UV_{355} were recorded between 0.09-0.21 cm^{-1} in unfiltered and decreased by 22% in filtered water. The concentration level of UV_{355} was lower than organic aromatic (UV_{254}), which may show that allochthonous NOM from terrestrial is part of autochthonous NOM in the water body. Furthermore, based on GIS, the catchment area of Cikapundung river pond is dominated by domestic activities and non-domestic activities. This may explain the high concentrations of NOM parameters and physical parameter of NOM in both filtered and unfiltered samples except for turbidity.

3.3. Correlation among physical characteristics and NOM in River Pond

Correlation among physical characteristics and NOM in Cikapundung River in unfiltered and filtered samples are shown in Table 4 and Table 5 respectively. There were strong correlations between COD and electrical conductivity in both filtered and unfiltered samples. Barakat *et al* [29] found similar result in Oum Er Rbia River which were polluted by agricultural and domestic activities. Conductivity and COD can be used as indirect chemical indicators of fecal contamination [30].

The correlation between COD and turbidity was strong but slightly lower than 95%. However, after filtering the correlation was insignificantly weak due to particle removal. The correlation between two parameters of chromophore NOM (UV_{254} and UV_{355}) in unfiltered sample and filtered sample were significant and strong. These were because the autochthonous NOM in the river water was dominated by terrestrial organic matter. In addition, the location of river pond is in the national forest park of Djuanda thus organic matter from this forest discharge directly to this pond.

Table 4. Correlation among physical characteristics and NOM on unfiltered sample.

		Turbidity	Conductivity	COD	UV_{254}	UV_{355}	TOC
Turbidity	Pearson Correlation	1					
	Sig. (2-tailed)						
Conductivity	Pearson Correlation	.877	1				
	Sig. (2-tailed)	.051					
COD	Pearson Correlation	.753	.923*	1			
	Sig. (2-tailed)	.142	.025				
UV_{254}	Pearson Correlation	.804	.506	.314	1		
	Sig. (2-tailed)	.101	.384	.607			
UV_{355}	Pearson Correlation	.873	.583	.379	.986**	1	
	Sig. (2-tailed)	.054	.302	.530	.002		
TOC	Pearson Correlation	-.038	-.419	-.575	.152	.205	1
	Sig. (2-tailed)	.952	.483	.311	.807	.741	

* Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed).

Table 5. Correlation among physical characteristics and NOM on filtered sample.

		Turbidity	Conductivity	COD	UV ₂₅₄	UV ₃₅₅	DOC
Turbidity	Pearson						
	Correlation	1					
Conductivity	Pearson						
	Correlation	.004	1				
COD	Pearson						
	Correlation	.055	.896*	1			
UV ₂₅₄	Pearson						
	Correlation	-.505	-.819	-.808	1		
UV ₃₅₅	Pearson						
	Correlation	-.434	-.868	-.831	.995**	1	
DOC	Pearson						
	Correlation	-.134	.784	.601	-.406	-.473	1
	Sig. (2-tailed)	.830	.116	.283	.498	.421	

* Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed).

In this study, there were no significant correlation between bulk organic NOM such TOC and DOC as well as organic parameters. This was due to many organic compounds which moderately contain organic carbon did not correlate with organic carbon which absorb significantly UV wavelengths, and chemical oxygen demand which exceed the standard.

4. Conclusion

The land use of the catchment area of Cikapundung river pond is dominated by anthropogenic activities which was furthermore affected water quality. Dissolved material plays crucial role on NOM parameters and electrical conductivity. Meanwhile the turbidity of the water mainly caused by non-dissolved material. There were significant and strong associations between COD and electrical conductivity as well as UV₃₅₅ and UV₂₅₄ in both filtered and unfiltered samples.

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