Assessment of Heavy Metal Contamination in Saguling Reservoir Water West Java Province Indonesia

Eka Wardhani[1,*], *Suprihanto Notodarmojo*[2], and *Dwina Roosmini*[1]

[1]Doctoral Program of Environmental Engineering Faculty of Civil and Environmental Engineering, Institut Teknologi Bandung-Indonesia
[2,3] Department of Environmental Engineering Faculty of Civil and Environmental Engineering, Institut Teknologi Bandung-Indonesia

Abstract. Saguling reservoir in West Java Province is becoming increasingly polluted by heavy metals. The purpose of this study was to determine the level of four heavy metals such as Cd, Cr, Cu, and Pb concentration at Saguling Reservoir at 12 sampling location. Water samples were collected during rainy and summer 2008-2017 to determine the spatial distribution seasonal and temporal variation of different heavy metal contents. Mean metals concentrations in summer seasons were Cd, Cr, Cu, and Pb higher than rainy season. Mean concentration of Cd, Cu, Cr, and Pb in water samples were accordance water quality standard in both season. Heavy metal pollution that occurs in the Saguling reservoir must be monitored because this reservoir is planned to be a source of raw water for Bandung City.

Keywords: **Assessment; Concentration; Heavy Metal; Saguling; Water.**

1 Introduction

Recently water pollution has become a extremely severe and visible form of environmental contamination as water bodies [1]. Heavy metals are one of the main pollutants of the environment, especially in urban areas. The pollution from industrial effluents, urban and agricultural waste in some rivers, reservoir, and water bodies has reached serious levels in Indonesia. Heavy metals are natural compounded elements occurring in the environment and different in concentrations along the earth crust. Although metals are natural constituents of our earth and they are present in all environments, their concentrations are drastically altered by man-made actions. The natural distributions of metals have been distressed in terrestrial and aquatic environment due to industrialization and urbanization in last few decades [2]. Heavy metals are natural trace components of the aquatic environment, but their levels have increased due to domestic, industrial, mining and agricultural activities [3-4]. Heavy metal concentrations can change during the year in the ecosystem, can also change during the growing season [5].

Saguling reservoir waters receive contaminants via local anthropogenic activities and through riverine inputs. This Reservoir was built on The Citarum River. The Citarum Watershed is home to the largest industrial area in West Java Province. Several economic activity are performed along Citarum River, including mining and agriculture.

The main objective of this paper was to determine level of selected heavy metals (Cd, Cr, Cu, Pb) concentration at Saguling Reservoir in the rainy and dry season.

2 Material and Methods

2.1 Study area

The Saguling is an artificial reservoir was built on the Citarum River, the largest river in West Java Province, in February 1985. The catchment areas of the reservoir or the upper Citarum River basin are faced with high population pressure. This is because over 50% of the population with a high annual growth rate (2.34% is the national average). The growth of population has caused the decrease of landholding and this condition forced them to extend their agricultural land by forest clearing and utilize marginal lands. As a consequence, there is a prevailing problem of floods accompanied by accelerated soil erosion in rainy seasons. Due to the high population density in the upper catchment of the reservoir, extensive agricultural land, soil erosion and the presence of industries, the reservoir water became polluted and alsocontaminated by heavy metals, pesticides, etc [6,7].

The maximum depth of Saguling reservoir during rainy and dry season is 46.4 meters and 30 meters respectively at station 9 (near Intake structure). The most shallow depth is at point 2 (Cihaur Village Cipeundeuy) which is 7.5 meters and 12.1 meters in the

* Corresponding author: ekw_wardhani@yahoo.com

rainy and dry season. Saguling reservoir is a reservoir with extreme depth fluctuations because the water catchment area has been damaged. The annual rainfall varies from 1,200 to 3,000 mm, with an average of 2,215 mm. The monthly rainfall during the wet season (November-April) is about 250 mm, varying from 100-500 mm. During the dry season (July-September) monthly rainfall usually is less than 50 mm based on data from the Meteorology, Climatology, and Geophysics Agency of West Java province [8].

2.2 Data collection

This study uses secondary data obtained from official documents of Indonesia Power Firm from 2008 to 2017. sampling location are presented in Table 1. Two stations (1A and 1B) were located in the Citarum River (Saguling reservoir inlet), eight stasions (2-9) located in the Saguling reservoir inundation, and two stations (10A and 10B) were located in the Citarum River (Saguling reservoir outlet). The 12 point of water sampling location around Saguling reservoir are presented in Figure 1. The main parameters in the analysis are the concentration of heavy metal (Cd, Cr, Cu, and Pb) in water.

Assessment of heavy metal contamination by comparing the concentration of heavy metal with water quality standards based on the Indonesian Republic Government Regulation no. 82 of 2001 concerning water quality management and water pollution control [9]. The water class used is class 3 for the cultivation of freshwater fish, livestock, water for irrigation, and or other uses requiring the same water quality as those uses. Data were analysis using Pearson correlation, the level of significance thereby being set at 5% (probability limit of p<0,05). Data analysis was done using Minitab Software 2016.

Table 1. Sampling stations in Saguling lake

Station	Location	Coordinate	
		South	East
1A	Citarum River Nanjung section	06º56'29.8"	107º32'10.7"
1B	Citarum River section Trash Boom Batujajar	06º54'58.9"	107º28'35.0"
2	Cihaur Village Cipeundeuy	06º53'13.5"	107º28'32.3"
3	Cimerang	06º53'13.4"	107º27'09.0"
4	Cihaur Estuary Maroko Village	06º54'13.0"	107º25'54.4"
5	Cipatik Estuary	06º56'07.6"	107º27'25.5"
6	Ciminyak Estuary-fishing floating located	06º57'14.6"	107º26'03.8"
7	Cijere Estuary	06º56'14.9"	107º24'50.8"
8	Cijambu Estuary	06º56'00.4"	107º22'22.4"
9	Near Intake Structure	06º54'54.4"	107º22'26.3"
10A	Tailrace	06º51'49,8"	107º20'57.0"
10B	Bantar Caringin	06º51'10,8"	107º20'58,0"

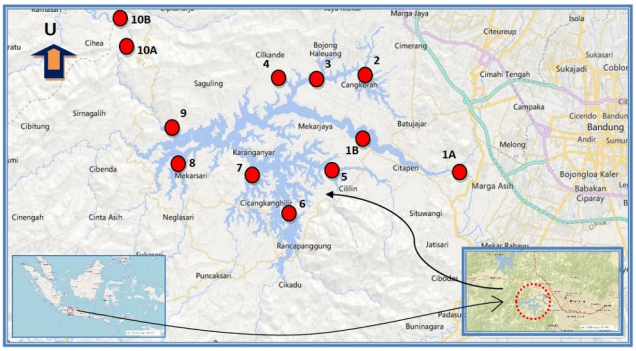

Fig. 1. Study Area and sampling location

3 Result and Discussion

3.1 Cadmium

During the rainy season of highest concentration at station 1A with concentration 0.007 mg/L and lowest at site 4,7,8 value 0.003 mg/L. The average concentration in the rainy and dry seasons is 0.005± 0.001 mg/L and 0.003±0.002 mg/L, respectively. The average concentration in the rainy season is greater than the dry season. The highest concentration of dry season is located at point 3 with the value of 0.006 mg/L and the lowest at the point 7 of 0.001 mg/L.

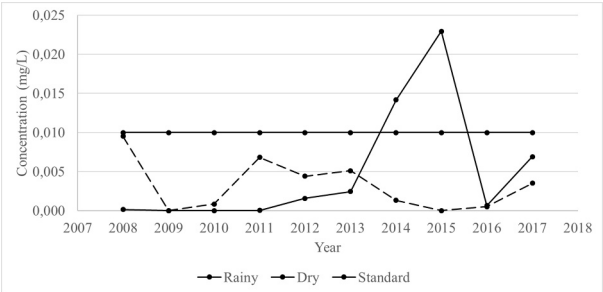

Fig. 2. Cd concentration in the last 10 years

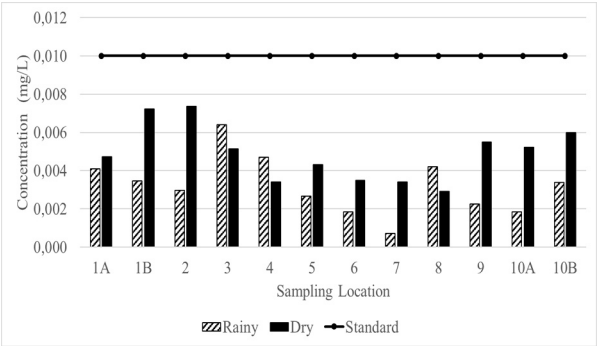

Fig. 3. Cd concentration at 12 point of water sampling location around Saguling Reservoir

The last 10 years Cd concentrations in the rainy season have decreased in the other hand during the dry season have increased. The last 10 years Cd concentrations meet the quality standard of 0.01 mg/L in all sampling points in the rainy and dry seasons except in 2014 and 2015 as described in the figure 2 and 3.

3.2 Chromium

Cr, as well as Zn, are the most abundant of the "heavy metals" with a concentration of about 69 mg/kg in the lithosphere. Cr occurs in nature mainly in the mineral chromite. The metallurgy industry uses the highest quality chromite ore whilst the lower-grade ore is used for refractory bricks in melting furnaces. Major atmospheric emissions are from the Cr alloy and metal producing industries. Cr^{6+} is a potent carcinogen and Cr^{3+} is an essential trace element [10].

The concentrations of Cr in Saguling reservoir water are shown in Figure 4 and 5. During the rainy season of highest concentration at station 3 with concentration 0.018 mg/L and lowest at site 10A and 10B. The average concentration in the rainy and dry seasons is 0.009± 0.005 mg/L and 0.003±0.002 mg/L, respectively. The average concentration in the rainy season is greater than the dry season. The highest concentration of dry season is located at point 9 with the value of 0.005 mg/L and the lowest at the point 10A and 10B. The last 10 years Cd concentrations in the rainy season and dry season the concentration trend has increased. The last 10 years Cr concentrations meet the quality standard of 0.05 mg/L in all sampling points in the rainy and dry seasons.

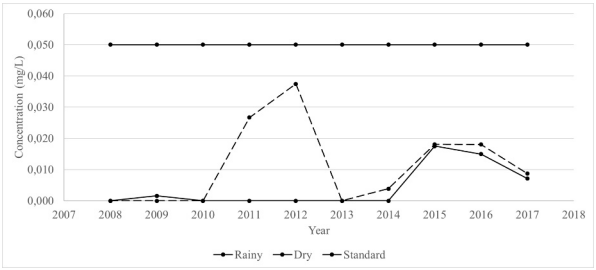

Fig. 4. Cr concentration in the last 10 years

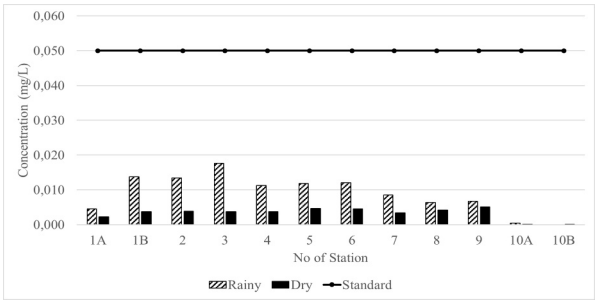

Fig. 5. Cr concentration at 12 point of water sampling location around Saguling Reservoir

3.3 Copper

Copper is an essential element for organisms and is also considered a priority pollutant by U.S. EPA [11]. Because of the widespread use of copper as an algicide, aquatic herbicide, fungicide, and bactericide, as well as discharges from smelting, refining, and other copper-producing industries, copper occurs in particulate, colloidal, dissolved, organic, and inorganic chemical forms [12].

During the rainy season of highest concentration at station 1A with concentration 0.026 mg/L and lowest at site 10A and 10B. The average concentration in the rainy and dry seasons is 0.019± 0.006 mg/L and 0.017±0.007 mg/L, respectively. The average concentration in the rainy season is greater than the dry season. The highest concentration of dry season is located at point 1A with the value of 0.034 mg/L and the lowest at the point 7 and 8. The last 10 years Cd concentrations in the rainy season and dry season the concentration trend has decreased. The last 10 years Cu concentrations does not meet the quality standard of 0.02 mg/L in some sampling points in the rainy and dry seasons as described in the figure 6 and 7.

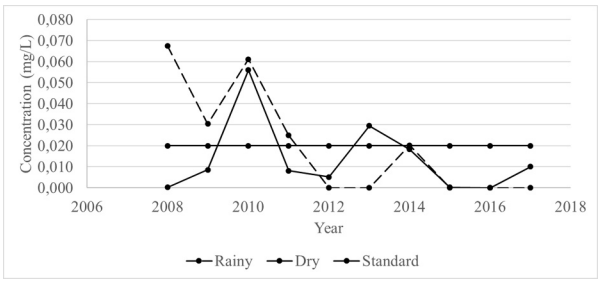

Fig.6. Cu concentration in the last 10 years

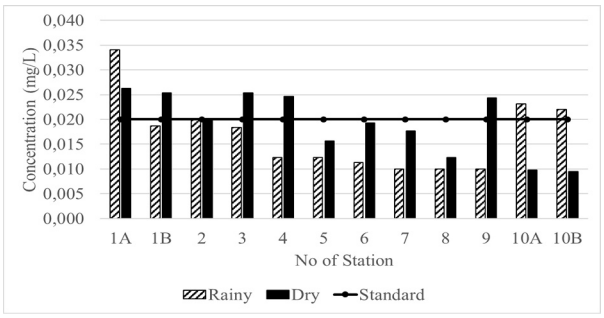

Fig. 7. Cu concentration at 12 point of water sampling location around Saguling Reservoir

3.4 Lead

The concentrations of Pb in Saguling reservoir water are shown in Figure 10 and 11. During the rainy season of highest concentration at station 10A with concentration 0.098 mg/L and lowest at site 7. The average concentration in the rainy and dry seasons is 0.025± 0.030 mg/L and 0.014±0.032 mg/L, respectively. The average concentration in the rainy season is greater than the dry season. The highest concentration of dry season is located at point 3 with the value of 0.113 mg/L and the lowest at the point 1A, 4, 5, 7 9, and 10B.

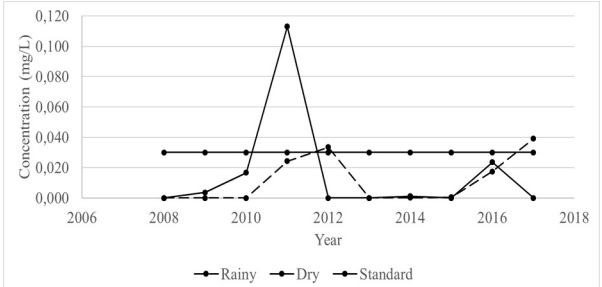

Fig. 8. Pb concentration in the last 10 years

The last 10 years Pb concentrations in the rainy season have increased in the other hand during the dry season has decreased. The last 10 years Cu concentrations meet the quality standard of 0.03 mg/L in all sampling points in the rainy and dry seasons except at 10A and 10B as described in the figure 8 and 9. In the rainy season the average order of heavy metal concentration from the largest is Pb>Cu>Cr>Cd while in dry season that is Cu>Pb>Cr=Cd

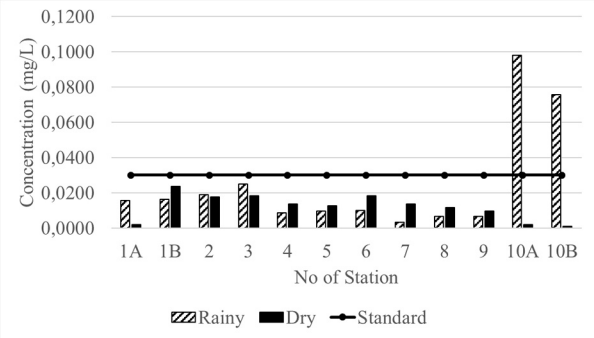

Fig. 9. Pb concentration at 12 point of water sampling location around Saguling Reservoir

3.6 Statistic Analysis

The significant phsycochemical parameters including pH, Dissolved Oxygen (DO), Total Dissolved Solid (TDS), temperature, hardness, and turbidity in rainy and dry seasons given in Table 4. pH value in rainy and dry seasons range between 7.1-7.7 and 7.2-7.6 respectively. The average pH value in dry season is greater than the rainy season. The average value of DO and temperature has some grade in the rainy and dry seasons. TDS, hardness, and turbidity are higher in rainy season than dry season. Heavy metals levels in water depend on the phsycochemical parameter of water such as pH, DO, TDS, temperature, hardness, and turbidity. It is well known that the solubility of toxic metals increases with the pH decrease [13].

In rainy season there is correlation between heavy metals with the exception of Cd. Pb have a negative correlation with Cr and Cu. Cr was correlated with Cu and Pb. A high correlation coefficient between heavy metals showed heavy metal having a common source, mutually dependent and identical behavior during the transport process. No correlation among heavy metals indicated that observed heavy metals were not controlled by a single factor, but controlled by a combination of phase geochemistry of the heavy metal content [13].

Table 4. Phsycochemical Parameter of studied Saguling reservoir water

Parameter	Phsycochemical parameter in rainy season					
	pH	**DO**	**TDS**	**Temp**	**Hardness**	**Turbidity**
		mg/L	**mg/L**	**ºC**	**mg/L**	**NTU**
Ave	7.3	2.9	211.7	27.2	67.1	23.2
Stdev	0.2	1.1	80.9	0.2	13.5	14.1
Max	7.7	5.5	366.9	27.6	91.7	62.6
Min	7.1	2.1	130.8	27.0	54.0	12.5
	Phsycochemical parameter in dry season					
Ave	7.4	2.9	160.0	27.3	46.5	20.3
Stdev	0.1	0.6	37.1	0.2	10.6	6.2
Max	7.6	4.0	234.6	27.7	66.6	30.0
Min	7.2	1.8	103.1	27.0	28.6	9.2

Pb has possitive correlation with DO, while Cr and Cu have negative correlation with DO. Cd, Cd and Cu have positive correlation with TDS. Cr was correlated with hardness and Cd was positive correlated with turbidity. Main factor influence of Cd concentration in water Saguling reservoir was turbidity while Cr, Cu, and Pb concentration in water influence with DO value. The correlation coefficients based on the relationship of the investigated heavy metals and some of phsycochemical parameter of Saguling reservoir in rainy season are presented in Table 5.

In dry season Cr was correlated with Pb while Cu was correlated with Cr. Cr has negative correlation with DO, while prositive correlation with temperature. Cu has negative correlation with DO, pH, and temperature while has positive correlation with turbidity. Main factor influence of Cr concentration in water Saguling reservoir was DO while Cu concentration in water influence with turbidity value. The correlation coefficients based on the relationship of the investigated heavy metals and some of phsycochemical parameter of Saguling reservoir in dry season are presented in Table 6.

Based on correlation pearson analysis concluded that during rainy season and drought physcochemical parameters that most influence concentration of heavy metal in Saguling reservoir water are DO and turbidity. According [14] concentration and toxicity heavy metals is influenced by hardness, pH, alkalinity and oxygen levels. The seasons also contribute to the concentration and solubility of heavy metals, which in the rainy season heavy metal concentration is lower due to the process of dilution by rain water. The dry season increases the concentration of heavy metals resulting from the water debit reaching minimum conditions, so that heavy metals concentrations are evenly distributed [15]. Based on [15] heavy metals concentration in water bodies is affected by climate and debit or current velocity, where the higher the discharge the concentration of heavy metals will be lower.

Table 5. Pearson correlation matrix for metal concentration, pH, DO, TDS, Temperature, and hardness in rainy season

Parameter	Cd	Cr	Cu	Pb	pH	DO	TDS	Temp	Hardness	Turbidity
Cd	**1**									
Cr	0.084	**1**								
Cu	0.157	0.621	**1**							
Pb	0325	-0.626	-0.618	**1**						
pH	0.423	0.231	0.029	0.201	**1**					
DO	0.198	-0.810	-0.692	0.916	-0.043	**1**				
TDS	0.651	0.597	0.498	-0.089	0.668	-0.361	**1**			
Temp	0.073	0.796	0.287	-0.541	0.413	-0.714	0.537	**1**		
Hardness	0.499	0.681	0.503	-0.281	0.601	-0.527	0.952	0.621	**1**	
Turbidity	0.703	0.199	0.310	0.046	-0.056	-0.058	0.524	-0.026	0.434	1

Table 6. Pearson correlation matrix for metal concentration, pH, DO, TDS, Temperature, and hardness in dry season

Parameter	Cd	Cr	Cu	Pb	pH	DO	TDS	Temp	Hardness	Turbidity
Cd	**1**									
Cr	0.051	**1**								
Cu	0.259	-0.640	**1**							
Pb	0.666	0.059	0.061	**1**						
pH	0.187	0.401	-0.330	0.467	**1**					
DO	-0.321	-0.563	-0.138	-0.152	-0.028	**1**				
TDS	0.491	-0.254	0.489	0.532	0.582	-0.091	**1**			
T	0.293	0.543	-0.347	0.498	0.698	-0.471	0.393	**1**		
Hardness	0.402	-0.483	0.551	0.422	0.465	0.129	0.954	0.228	**1**	
Turbidity	0.399	-0.291	0.658	-0.050	-0.367	-0.227	0.206	-0.247	0.265	1

4 Conclusion

It can be concluded that the spatial and seasonal distribution of heavy metals in the water from Saguling reservoir West Java Province the concentrations of Cd, Cr, Cu, and Pb determined were very low and below the detection limit. Apparently, the Cu and Pb concentrations were determined highest at inlet and outlet Saguling Reservoir. The average concentration of Cd, Cr, Cu, and Pb in the rainy season is greater than the dry season. Heavy metals concentration in water bodies is affected by season and debit or current velocity, where the higher the discharge the concentration of heavy metals will be lower. The concentrations of Cd, Cr, Cu, and Pb is controlled by the association of heavy metals with dissolved oxygen and turbidity.

Acknowledgement
Authors would like to acknowledge State Minister for Research and Technlogy and Higher Education Republic Indonesia for financial support for the research.

References

1. Francis, B.M. *Toxic substances in the Environment*, (John Wiley and Sons, Inc, NewYork, 1994).
2. Banerjee, A.D.K. Environmental Pollution, 123, 95 10. (2003)
3. Leland, H.V., Luoma, S.N., and Wilkes, D.J. J. Wat. Poll. Control Fed., 50: 1469-1514. (1978)
4. Mance, G.. Elsevier. London (1987)
5. Li F, Huang J, Zeng G, Yuan X, Li X, Liang J, Wang X, Tang X, Bai B. Journal of Geochemical Exploration 132:75 83 (2013)
6. Report PT Indonesia Power UBP Saguling 1. http://www.indonesiapower.co.id
7. Annual Report Meteorology, Climatology, and Geophysics Agency of West Java province.,2018
8. Indonesian Republic Government Regulation no. 82 of 2001 concerning water quality management and water pollution control
9. Annual Report West Java Province Environmental Agency., 2018
10. Reza R, Singh G. Int. J. Environ. Sci.Tech.**7 (4)**,785-792 (2010)
11. U.S. Environmental Pollution Agency (1980) ambient water quality criteria for copper, EPA. Criteria and Standards Divission, Washington, DC
12. Leckie JO, Davis JA III (1979) Aqueous environmental chemistry of copper in Nriagu JO (ed) Copper in the Environment, Part I : Ecological Cycling Wiley-Interscience, NY
13. Anand, J.B.D. and Kala, M.J.S. Int. Res. J. Environ. Sci., 4(2): 22-31 (2015).
14. Yudo, S. Jurnal Air Indonesia*, 2*(1). (2011).
15. Prartono, T., dan Nurjaya, I. W. Jurnal Ilmu dan Teknologi Kelautan Tropis, 8(1). (2016).