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*Department of Civil and Environmental Engineering, Institut Teknologi Bandung,  
Bandung, Indonesia*

Corresponding author's email: ekw\_wardhani@yahoo.com

Saguling lake 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 quality of water in the Saguling Lake has been monitored since 1990 by the state agency for environmental control; there are no reports about heavy metals in sedimen of the lake. There is insufficient information for an assessment of heavy metas distribution in the lake. Originally, the Saguling was planned for a single purpose lake to generate electricity. Later, considering the environmental problems of the area, the Saguling was re-planned as a multipurpose lake such as fisheries, agri-aquaculture, and tourism. But, at present, the lake is also used for domestic purposes such as raw water, bathing and washing. Therefore, the aim of this work is to quantity Cd, Cr, Cu, Ni, Pb, and Zn levels in the core sediments of Saguling Lake section Nanjung, Batujajar, and Maroko. Metals Pollution Index were used for the environmental assessment of Saguling Lake sediment. The concentration of heavy metals in the core sediment decreased in the order of  $Zn > Cu > Cr > Pb > Ni > Cd$ . Zn was the most abundant metals in Saguling Lake sediment, with measured concentrations ranging from 87.24 to 314.49 mg/kg, follow by Cu (78.32-112.12 mg/kg), Cr (30.86-74.96 mg/kg), Pb (15.05-40.82 mg/kg), Ni (6.50-20.08 mg/kg), and Cd (6.85-10.12 mg/kg). The section was polluted by Cd and Cu based on MPI catagory, whereas there is no pollution for Cr, Pb, Zn, and Ni. The possible source for hevy metals contamination were attributed to the increasing municipal and industrial wastewater discharges, agricultural runoff, which may be associated with an accelerating growth of economic in the Saguling Lake region in the past decade.

**Keywords:** Contamination Factor, Heavy Metals, Saguling, Sediment, Metal Pollution Index.

## **1. INTRODUCTION**

Lake are the important reservoir for many persistent pollutant which accumalate in aquatic organisms and bottom sediments. The heavy metals in aquatic systems could be transported rapidly in to the sediments, where they could be released from sediments in case of changes in environmental condition, thus resulting in a secondary contamination source affecting the ecosystem in the lake. Sediments are both carriers of heavy metals an potential source in the aquatic systems (Liu, 2011).

Sediment represents the largest place of metals in aquatic environments (Daskalakis and O'Connor, 1995). More than 90% of the heavy metals load in aquatic systems is bound to suspended particulate matter and sediments (Calmaroet al., 1993). Sediments are polluted with

various kind of hazardous and toxic substances have been found, including trace element which is accumulated in sediment via several pathways, disposal of liquid effluent, terrestrial runoff, carrying chemical originating from numerous urban, industrial, and agricultural activities, as well as atmospheric deposition (Rival Da Silva, et al., 1996 Karageorgis et al., 2002; Mucha et al., 2003). The distribution of heavy metals in sediment in populated area can provide researchers with evidence of the anthropogenic impact on ecosystems and assessing the risks associated with discharged human waste. The increasing of metals in sediments has significant environmental impact for local communities, as well as for aquatic water quality (Deniraket al.,2006).

The Saguling Lake area is 4.710 Ha the water storage capacity is 730,5 million m<sup>3</sup>. The surrounding area of Saguling Lake is hilly, while the river has many tributaries at this location. This makes the shape of Saguling Lake very irregular or dendritic, with many extended bays. The lake area was formerly densely populated by farmer population with extensive agricultural lands. The catchment areas of the lake or the upper Citarum River basin are faced with high population pressure. This is because over 50% of the population consists of farmers with a high annual growth rate (2.34% is the national average). The growth of farmer 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 lake, extensive agricultural land, soil erosion and the presence of industries, the lake water became polluted and eutrophic. The growth of aquatic weeds has been accelerated, with frequent blooms of *Microcystis* algae. The water is also contaminated by heavy metals, pesticides, etc. An extensive growth of water-hyacinth is maintained by fencing to reduce pollutant contents of water at inlets of the Citarum River (Indonesia Power, 2015).

Hence, the main aspects of the present work are to (1) determine the content of heavy metals (Cd, Cr, Cu, Ni, Pb, and Zn) in saguling lake core sediment. (2) Calculate the Metals Pollution Index (MPI) in order to assess quality of the sediment.

## 2. RESEARCH METHODOLOGY

Core sediment samples were collected from three different sampling in Saguling lake in July 2015, sampling location are presented in Table 1. The point chosen because of their classification as having poor water quality accoding to water monitoring report (Indonesia Power, 2015). The sampling locations were recorded (latitudinal and longitudinal position) using hand-held Global Positioning System (GPS). The core was 50 cm long and taken using PVC tube. The inside diameter of the coring tube was 50 mm. The sediment core was immediately sliced in thin section (10 cm each) with a plastic cutter. Samples were then placed into polyethylene bags, and returned to the laboratory and stored in a freezer. For the heavy metals analysis, the samples were then grounded using pestle and mortar until all particles passed a 200-mesh nylon sieve.

Table 1: Sampling Stations on Saguling Lake

No	Location	Coordinate	
		S	E
1	Nanjung section	06°56'29.8"	107°32'10.7"
2	Batujajar section	06°54'58.9"	107°28'35.0"
3	Maroko section	06°53'13.5"	107°28'32.3"

For the trace metals analysis, 500 mg of sediment was digested with 1 ml HNO<sub>3</sub>, 3 ml HF, and 3 ml HCl at a temperature of 90-190°C for 16 h. The residue was then diluted to with deionized

water and analyzed for 6 trace element (Cd, Cr, Cu, Ni, Pb, and Zn) by inductively coupled plasma-mass spectrophotometry (ICP-MS).

### 3. RESULT AND DISCUSSIONS

#### 3.1. Heavy metals concentration in Saguling Lake

The total heavy metals contents in the core sediment decrease in order of Zn>Cu>Cr>Pb>Ni>Cd. Vertical variations of heavy metals in sediment core Nanjung section are presented in Figure 1. The range concentration measured heavy metals contents in Nanjung Section shows in Table 2.

Table 2: Range concentration of heavy metals in Nanjung Section

Variables	Cd	Cr	Cu	Ni	Pb	Zn
Concentration (mg/kg)	8.10-10.12	53.76-74.96	78.32-112.12	11.60-20.08	20.12-40.82	162.46-314.49
Average (mg/kg)	9.12	64.44	97.88	15.92	29.51	239.71
Standard* (mg/kg)	1.50	80.00	65.00	21.00	50.00	200.00

\*ANZECC, 1997

In the Nanjung study site heavy metals Cd and Cu concentration did not fulfill the quality standard based on Australian and New Zealand Environment and Conservation Council (ANZECC, 1997). High concentrations of Cd and Cu were originated from industries located in the basin of Citarum River which is the catchment area for Saguling.

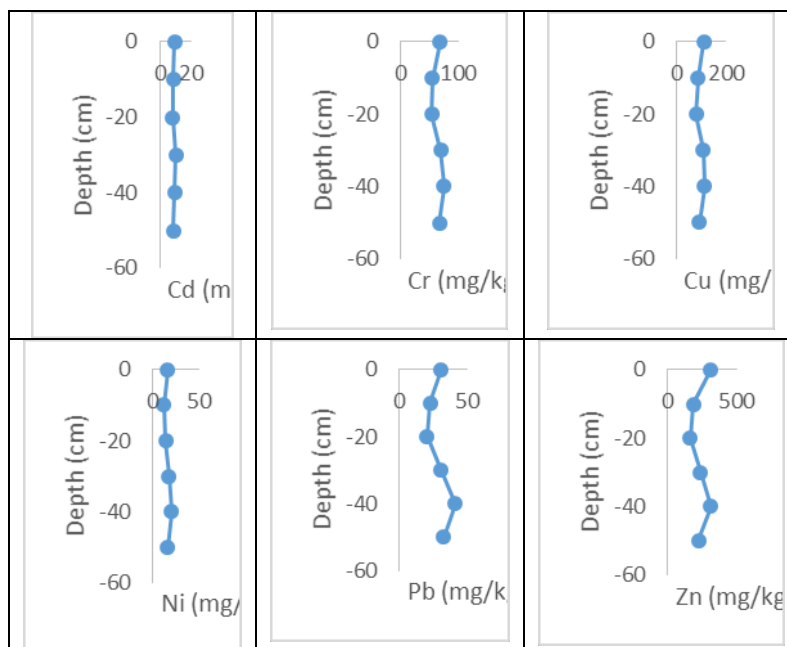


Figure 1: Vertical variations of heavy metals in sediment core Nanjung section

The vertical profiles of heavy metals in sediment core Batujajar section are shown in Figure 2. According to the mean concentration of heavy metals in sediment profiles, the content of the most metals in surface sediment are generally higher than those in deeper layers. Compared with

ANZECC, 1997 only the concentration of Cd and Cu were above the standard. The total heavy metals contents in the core sediment decrease in order of Zn>Cu>Cr>Pb>Ni>Cd. It can be seen at Figure 2 that the highest concentration is observed in surface sediment, but for Cr, Cu, Ni, Pb, and Zn concentration were observed at 30-40 cm depth. Table 3 shows the range concentration of heavy metals in the sediments of the Saguling Lake.

Table 3: Range concentration of heavy metals in Batujajar Section

Variables	Cd	Cr	Cu	Ni	Pb	Zn
Concentration (mg/kg)	6.85-8.77	31.89-52.55	79.17-100.16	7.01-9.41	15.05-22.71	87.24-139.53
Average (mg/kg)	7.66	36.97	90.43	8.13	17.29	110.18
Standard* (mg/kg)	1.50	80.00	65.00	21.00	50.00	200.00

\*ANZECC, 1997

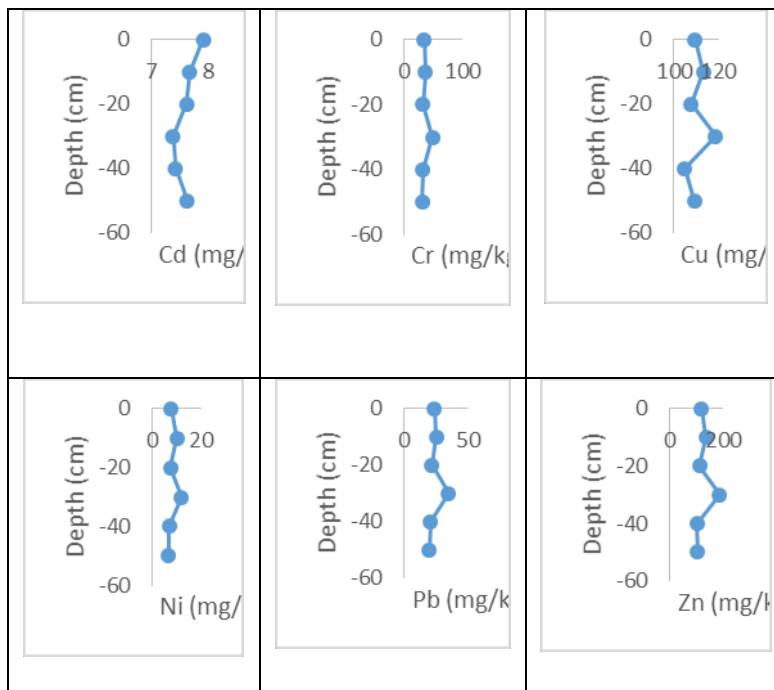


Figure 2: Vertical variations of heavy metals in sediment core Batujajar section

The total heavy metals contents in the core sediment decrease in order of Zn>Cu>Cr>Pb>Ni>Cd. Vertical variations of heavy metals in sediment core Maroko section are presented in Figure 3. Compared with ANZECC, 1997 only the concentration of Cd and Cu were above the standard. From the figure, the measured heavy metals contents varied greatly as follows: Cd, 7.38-7.90 mg/kg; Cr, 30.86-48.16 mg/kg; Cu, 104.95-118.61 mg/kg; Ni, 6.50-12.00 mg/kg; Pb, 19.46-34.52 mg/kg; and Zn, 100.68-185.95 mg/kg. Tabel 4 shows range concentration of Heavy Metals in Maroko Section.

Table 4: Range concentration of heavy metals in Maroko Section

Variables	Cd	Cr	Cu	Ni	Pb	Zn
Concentration (mg/kg)	7.38-7.90	30.86-48.16	104.95-118.61	6.50-12.00	19.46-34.52	100.68-185.95
Average (mg/kg)	7.60	35.65	110.52	8.41	24.07	126.28
Standard* (mg/kg)	1.50	80.00	65.00	21.00	50.00	200.00

\*ANZECC, 1997

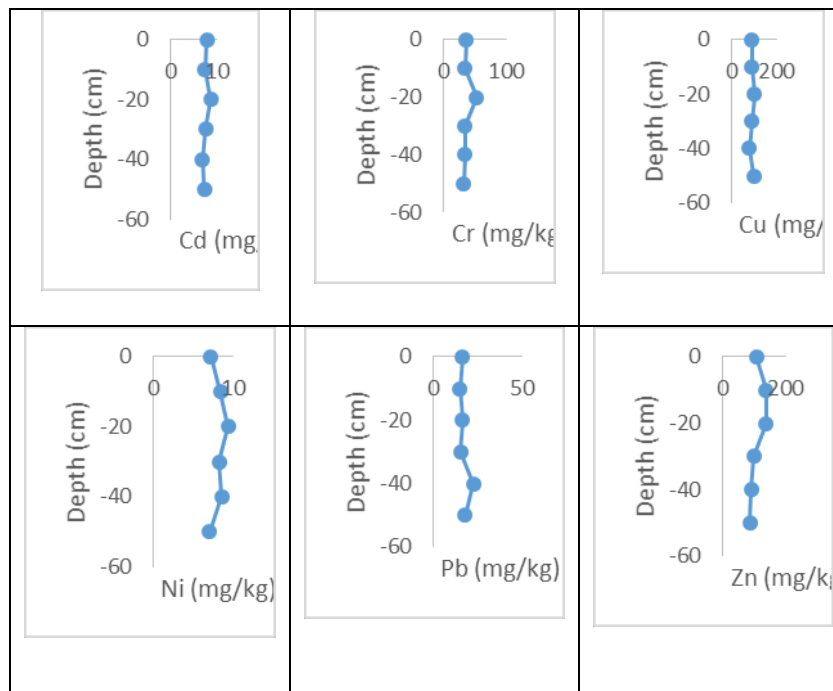


Figure 3: Vertical variations of heavy metals in sediment core Maroko section

The maximum, minimum, and average value of 6 heavy metals in the sediment cores are presented in Table 5. Cd and Cu concentrations did not fulfill the quality standard based ANZECC, 1997. The concentration of Cd and Cu in Nanjung section the highest compared to the other two locations. Cd and Cu concentration is greater than the average crust has occurred indicating enrichment of both these metals as a result of anthropogenic activities.

Table 6 presented mean concentration of measured elements in lake sediment samples from different countries along with present study. Comparing with the data from other country, the heavy metals concentration in Saguling lake were found higher. Heavy metals concentration in Saguling Lake must be considered from the government because the lake Saguling functions are related to public health as a source of irrigation water, fisheries, and raw water sources of drinking water for Bandung Basin and surrounding region.

Table 5: The maximum, minimum, and average value heavy metals in the sediment cores

	Cd	Cr	Cu	Ni	Pb	Zn
Nanjung Sediment Core						
Maximum	10,12*	74,96	112,12*	20,08	40,82	314,49
Minimum	8,10*	53,76	78,32*	11,60	20,12	162,46
Mean	9,12*	64,44	97,88*	15,92	29,51	239,78
Batujajar Sediment Core						
Maximum	7,91*	48,16	118,61*	12,00	34,52	185,97
Minimum	7,38*	30,86	109,95*	6,50	19,46	100,68
Mean	7,60*	36,65	110,52*	8,41	24,07	126,28
Maroko Sediment Core						
Maximum	8,77*	52,55	100,16*	9,41	22,71	139,53
Minimum	6,85*	31,89	79,17*	7,01	15,05	87,24

Mean	7,66*	36,97	90,43*	8,13	17,29	110,18
ANZECC ISQG-Low <sup>a</sup>	1,50	80	65	21	50	200
Average crush <sup>b</sup>	0,30	90	45	68	20	95

\*Did not appropriate with based on ANZECC, 1997 standard, <sup>a</sup>ANZECC, 1997 <sup>b</sup>Turkerian and Wedepohl, (1961)

Table 6 Mean concentration of measured elements in lake sediment samples from different countries along with present study

No	Nama of the lakes	Heavy metals concentrations (mg/kg)					
		Cd	Cr	Cu	Ni	Pb	Zn
1	East lake, Wuhan, China <sup>a</sup>	-	-	54.8	-	40.3	138
2	Songkhla lake, Southern Thailand <sup>b</sup>	0.1-2.4	-	1.8-125	2.5-21.9	8.2-131	5.4-562
3	Laguna lake Philippines <sup>c</sup>	0.02-0.09	-	9.7-18.7	9.7-18.7	17-23	10.3-18.3
4	Manchar lake, Pakistan <sup>d</sup>	4.9-9.7	14.7-26.8	15.6-29.7	16.1-26.6	14.6-20.9	53.9-154
5	Taihu lake, China <sup>e</sup>	0.94	56.2	36.7	-	51.8	-
6	Hussainsagar lake, India <sup>f</sup>	-	40-60	-	170-210	40-60	-
7	Saguling lake, Indonesia <sup>g</sup>						
	Nanjung	9,12	64,44	97,88	15,92	29,52	239,72
	Batujajar	7,60	35,65	110,52	8,41	24,07	126,28
	Maroko	7,66	36,97	90,43	8,13	17,29	110,18

<sup>a</sup>Yang et al. 2007; <sup>b&c</sup>Pradit et al. 2010; <sup>d</sup>Arain et al. 2008; <sup>e</sup>Yin et al. 2011; <sup>f</sup>Gurunadha et al. 2008; <sup>g</sup>present study

### 3.2. Assessment of sediment contamination

Tomlinson, 1980 has developed a simple method based on Metals Pollution Index (MPI) to assess the degree of pollution by metals in aquatic sediments. PI was calculated using the equation

$$CF = \frac{C_{Metal}}{C_{background}} \quad (1)$$

$$MPI = (CF_1 \times CF_2 \times CF_3 \dots \times CF_n)^{1/n} \quad (2)$$

Where, CF is the contamination factor,  $C_{metals}$  is the concentration of pollutants in sediment,  $C_{background}$  is the background value for the metals, and n the number of metals. Background concentration of Cd, Cr, Cu, Ni, Pb, and Zn was respectively 0.30 mg/kg, 90 mg/kg, 45 mg/kg, 68 mg/kg, 20 mg/kg, and 95 mg/kg (Turkerian and Wedepohl, 1961). The MPI value of > 1 is polluted whereas < 1 indicates no pollution. MPI value calculated is summarized in Table 7. According to MPI value Saguling lake sediment was polluted with Cd and Cu, whereas no pollution of Cr, Pb, Zn, and Ni was found.

Table 7: Metals Pollution Index Saguling Lake

Metals	MPI Value	Catagory
Cd	26,93	polluted
Cu	3,53	polluted
Cr	0,03	no pollution
Pb	0,48	no pollution
Zn	0,11	no pollution
Ni	0,00	no pollution

### 4. CONCLUSION

The heavy metals were identified in the sediment profile in Nanjung, Batujajar, and Maroco section in Saguling Lake. The highest concentration of heavy metals were found at the top of sediment core. The total heavy metals contents in the core sediment decrease in order of Zn>Cu>Cr>Pb>Ni>Cd. Nanjung section shown the highest contamination of heavy metals. The possible main source of the metals contamination in the sediment are municipal and industrial wastewater discharge, agriculture runoff, and atmospheric input. Based on MPI value Saguling lake sediment is polluted as far as Cd and Cu are concerned whereas there is no pollution for Cr, Pb, Zn, and Ni.

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