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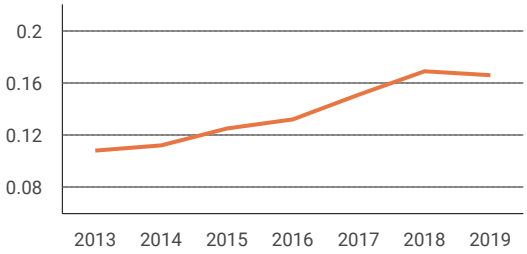

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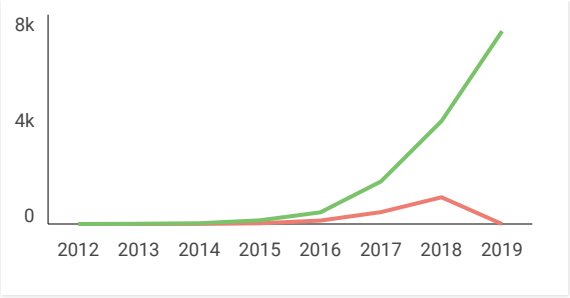

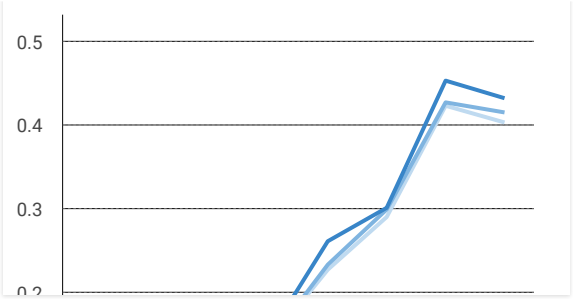

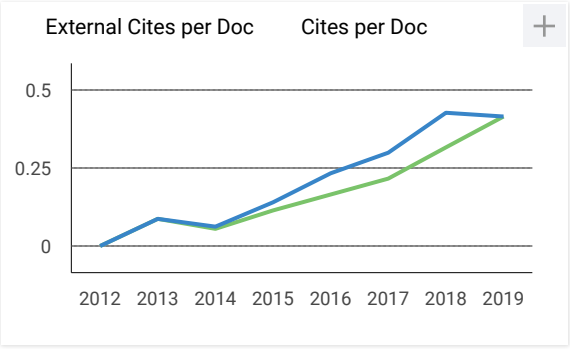

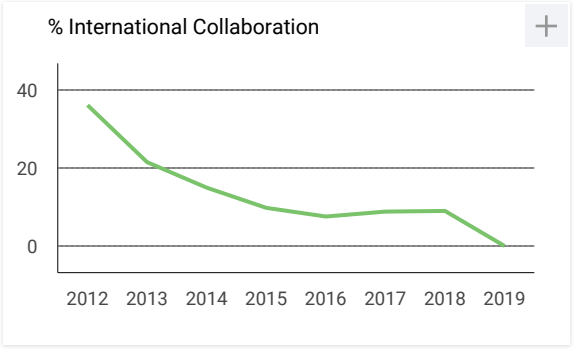

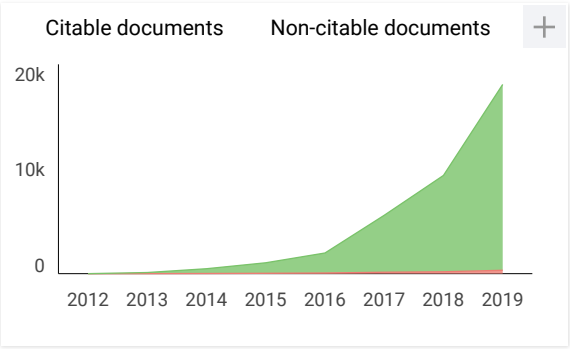

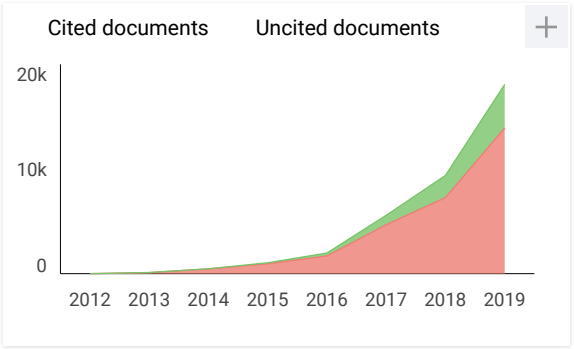

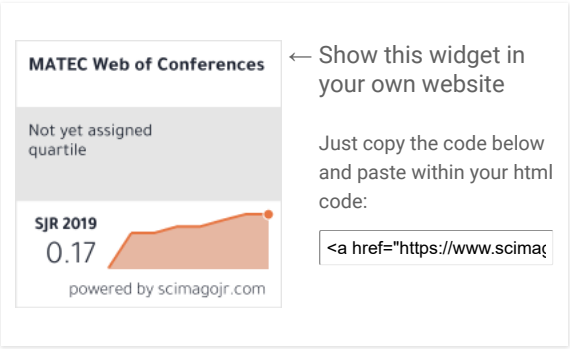

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Stream Sediment Geochemical Survey of Selected Element In Catchment Area Of Saguling Lake

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Abstract. Saguling Lake is one of the largest lakes in West Java Province that accommodates domestic and non-domestic wastes via the Citarum River as its main water source. This study aims to determine the geochemical background concentration (Cbg) in water catchment area of Saguling Lake. The knowledge of the Cbg of heavy metals is essential for defining pollution, identifying the source of contamination, and for establishing reliable environmental quality criteria for sediments. The value of Cbg will be used for assessment of the sediment quality in Saguling Lake. Assessment of sediment quality is very important to determine the actual condition of water in the lake and as the basis for management of waters environment in the future. The search was taken at 22 sampling points in the unpolluted water catchment area. Samples were collected and analyzed for Cd, Cr, Cu, and Pb. Each sample was digested in agua regia and analyzed by ICP-EOS. Results showed Cbg which are: Cd 0.34 ± 0.10 mg/kg, Cr 110.57 ± 28.61 mg/kg, Cu 49.93 ± 9.28 mg/kg, and Pb 18.62 ± 9.83 mg/kg. Based on the assessment result, it is concluded that the sediment quality in Saguling Lake is categorized as polluted by Cd, Cr, Cu, and Pb metals.

1 Introduction

The Sediments are the layers of relatively finely divided matter covering the bottoms of river, streams, lake, and oceans. Sediment typically consists of mixture of fine, medium, and coarse grained minerals, including clay, silt, and sand mixed with organic matter. They may vary in composition from pure mineral matter to predominantly organic matter. Sediments are lake of a variety of biological, chemical, and pollutant detritus in bodies of water and are repositories of pollutants such as heavy metals and organic compounds. Of particular concern is the transfer of chemical species from sediment into aquatic food chains via organisms that spend significant parts of their life cycles in contact with or living in sediment [10].

Sediment constitutes an integral and dynamic part of a stream basin, originating from weathering of minerals and soils up stream. Natural concentrations of heavy metal as a result of the weathering process of mineral deposits can be quite high in stream sediments close to the deposit, but decrease with increasing distance downstream, due to dissipation energy and dilution of sediments from other not polluting source [12].

The term "geochemical background" was first introduced by geochemistry explorers in the mid-twentieth century to distinguish between the un-mineralized element abundance and the mineralized one from rock formations. In the last few decades "Geochemical background concentration (Cbg)" has become one of the most important terms in environmental science. Cbg is used to distinguish pollution occurring in environment whether the source of pollutant comes from human activities or from natural phenomena (geogenic/biogenic) [13]. The adaptation process of Cbg in environmental science generates wider meanings and applications. Currently Cbg is applied not only to rocks, minerals, and sediments but also to water and air [13,7].

Cbg is the concentration of metal derived from the weathering of original rocks of the earth's crust without any addition of anthropogenic activity [9]. Cbg is very specific depending on the structure of rocks forming it. There are many Cbg terms in geology such as ambient background, area background, natural background, naturally occurring background, Pedogeochemical background, and pre-industrial background [13]. Evaluation of Cbg is essential since it generates impact for assessment of environmental risk and the determination of regulations related to the environmental baseline of elemental pollution [13].

The purpose of this research is to identify the Cbg of 4 types of heavy metals i.e. Cd, Cr, Cu, and Pb from water catchment area of Saguling Lake. The value of Cbg will be used as a basis to determine the sediment quality in the lake. Monitoring on sediment quality

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should become an integral part of water quality management and water pollution control program considering that sediment is the site for accumulation of pollutants including heavy metals.

2 Material and methods

2.1 Sample collection and chemical analysis

Stream sediment samples were collected using hand trowel from 22 different points in Catchment area of Saguling lake, in November 2015 sampling location are presented in Table 1. The sampling locations were recorded (latitudinal and longitudinal position) using hand-held Global Positioning System (GPS). The location of sampling were selected based on criteria that these locations are in areas that have not been contaminated by human activity. Sampling sites are scattered in the water catchment area of Saguling Lake and concentrated in Southern part which is relatively less contaminated than the Northern or Eastern part.

Table 1. Sampling location catchment area of Saguling lake

No	South	East	Location
1	6°47'34.66"	107°34'39.07"	Kertawangi
2	6°48'52.80"	107°42'30.66"	Pasir Buleud
3	6°52'24.84"	107°42'52.00"	Melatiwangi
4	6°56'32.30"	107°32'09.70"	Nanjung
5	6°58'30.00"	107°36'30.00"	Cisirung
6	6°59'28.50"	107°37'35.30"	Dayeuhkolot
7	7°01'58.20"	107°40'36.28"	Ciheulang
8	7°04'29.00"	107°44'53.00"	Wangisagara
9	7°08'43.05"	107°41'57.00"	Babakan
10	7°09'13.14"	107°42'34.17"	Pacet
11	7°10'21.76"	107°39'41.60"	Halimun Mt
12	7°11'36.62"	107°38'46.49"	Margamukti
13	7°12'06.02"	107°39'55.00"	Cibeureum
14	7°12'30.14"	107°39'20.16"	Cisanti Lake 1
15	7°12'35.87"	107°39'24.10"	Cisanti Lake 2
16	7°12'40.12"	107°39'31.71"	Cisanti Lake 3
17	7°13'03.60"	107°39'22.50"	Cisanti Lake 4
18	7°10'09.12"	107°42'36.69"	Cihawuk
19	7°13'22.78"	107°41'26.65"	Guha Mt 1
20	7°13'22.78"	107°41'26.65"	Guha Mt 2
21	7°12'40.44"	107°39'09.01"	Wayang Mt 1
22	7°12'40.44"	107°39'09.01"	Wayang Mt 2

Samples were then placed into polyethylene bags, and refrigerated at 4° C. They were analyzed in the laboratory. Each sediment sample was dried at 50°C, the samples were then grounded using pestle and mortar until all particles passed a 200-mesh nylon sieve. This fraction is mainly contained silt and clay; Thus, this fraction may adsorb a higher heavy metal concentration. The extraction of heavy metals were made using conventional digestion procedure of sediment samples, which consists of digesting aliquots of 1 g of dry sediment was weighted into Teflon beakers, to which a mixture of concentrated HNO_3 : HCl (3:1) was added and digested in a water bath during 3 h at 120°C. The concentration of Cd, Cr, Cu, and Pb, were determined for each sample using an Inductively Coupled Plasma Optical Emission Spectrometry or *ICP-OES.*

Currently there are various geochemical indices to be used in assessment of the quality of sediments in waters related to heavy metal pollution. The indices include Contamination Factor (CF). Both indexes assess the quality of sediment at each sampling point. Data of Cbg shall be used to determine the quality of sediments at 12 points in Saguling lake. Assessment of sediment quality in Saguling lake uses the method of CF. The 12 points of sediment sampling locations around Saguling lake are presented in Table 2 and Figure 1.

Table 2. Sampling locations

No	South	East	Location
1A	06°56'29,8"	107°32'10.7"	Citarum River Nanjung section
1B	06°54'58,9"	107°28'32.3"	Sungai Citarum *Trash Boom* Batujajar
2	06°53'13,5"	107°28'32.3"	Cihaur Kampung Cipeundeuy
3	06°53'13,4"	107°27'09.0"	Cimerang
4	06°53'13,0"	107°25'54.4"	Muara Cihaur Kampung Maroko
5	06°56'07,6"	107°27'25.5"	Muara Cipantik
6	06°57'14,6"	107°26'03.8"	Muara Ciminyak-lokasi perikanan jaring terapung
7	06°56'14,9"	107°24'50.8"	Muara Cijere
8	06°56'00,4"	107°22'22.4"	Muara Cijambu
9	06°54'54,4"	107°22'26.3"	Dekat *Intake Structure*
10A	06°51'49,8"	107°20'57.0"	*Tailrace*
10B	06°51'10,8"	107°20'58.0"	Bantar Caringin

Fig. 1. Study area and sampling stations in Saguling Lake West Java

The level of sediment contamination by heavy metals is often expressed in CF in the following equation:

$$CF = \frac{Cme}{Cbg} \quad (1)$$

Where C_{Me} is the concentration of metals in the sediment samples (mg/kg) [17]. This method compares the concentration of one type of heavy metal to the background heavy metal which is the concentration of the original heavy metals derived from the earth's crust. The results of the calculation by this CF method are compared with some grade of pollution levels as presented in Table 3.

Table 3. Catagory class of sediment quality with CF [17]

CF value	Level of Pollution
CF <1	Low
1 ≤ CF ≥ 3	Moderated
3 ≤ CF ≥ 6	Considerable
CF> 6	Very high

3 Results and disscussion

3.1 General and local geological setting

The catchment area of Saguling lake is a basin area of Bandung. The greater Bandung area is a large intra-montane basin surrounded by volcanic highlands. The central part of basin has an altitude of about 665 m and surrounded by up to 2.400 m. Tertiary and quaternary volcanic terrain. The basin measures about 45 x 45 km and has a total area of 1.830 km^2. The basin is surrounded by volcanic mountains, which are the lowest at the north-west side. On the side, the Saguling lakes is located. The main river, the Citarum springs at Situ Cisanti 78 km upstream of the lake. In the basin about 200 major tributaries with corresponding sub basins can be distinguished. Citarum river with its tributaries forms the main drainage systems of the basin catchment. Deposits in the basin comprise of course volcanic lastics, fluvial sediments and notably a thick series of lacustrine deposits. The climate of the basin of the basin is relatively cool compare to the rest of Indonesia, with temperature mostly between 20 and 30^oC. 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 [16].

The greater Bandung basin area encompasses five administrative units which are Bandung municipality, Cimahi municipality, Bandung regency, West Bandung regency plus part of Sumedang regency (3 village). Large population growth and urbanization is taking place in the greater Bandung Basin. In 1995, the population was about 2.5 million and in 2010 the population grew to 7.8 million. It is commonly believed that this urbanization will continue, but it is very uncertain to what extent. In addition with expansion of manufacturing and textile industries in Bandung basin urbanization was increased. The population growth need for an enormous increase of settlements in the basin. Various types of industries scattered in regencies and cities in the Saguling Lake water catchment area comprises 556 industries, of which 442 industries are textile that are the largest. In addition to textile industry, there are 8 units of paper industry, 11 units of leather tanning, 16 units of plastic and rubber industry, 14 units of chemical industries, 40 units of metal and electroplating, 25 units of food and beverages. They are spread in various regions, mostly in Bandung regency of 325 industries followed by Cimahi City 101 industries and 90 industries in Bandung City. Source of pollution. The textile industry, paper industry, leather industry and food-beverage industry are potential to become the sources of high organic substance pollution load, while metal and metal coating industries are potential to dispose of heavy metals [16].

3.2 Background concentration

Concentrations of Cd, Cr, Cu, and Pb at 22 Stream sediments located in the Saguling lake water catchment are presented in Figure 2.

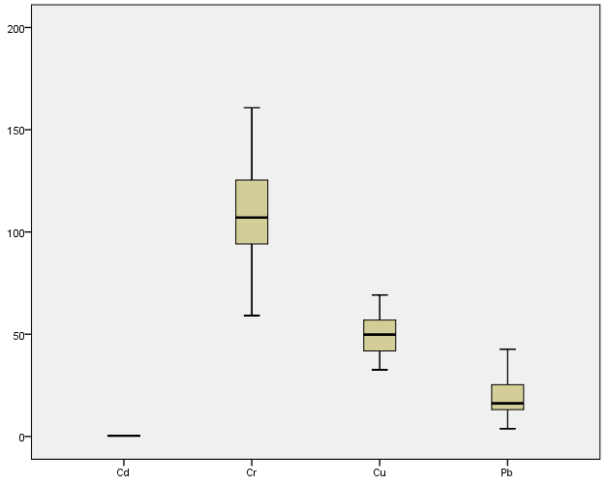

Fig. 2. Concentrations of Cd, Cr, Cu, and Pb in Catchment Area of Saguling lake (mg/kg)

Concentration of Cd in catchment area of Saguling lake ranges from 0.17-0.53 mg/kg, the mean value 0.34 mg/kg. The lowest concentration in sampling point 7 (Ciheulang) and the highest in sampling point 11 (Halimun Mountain). Concentration of Cd in the earth's crust is 0.1 mg/kg while in average the concentration of Cd in the world's soil is 0.3 mg/kg [11,19]. Cd concentration in the Catchment area of Saguling lake is relatively higher than the concentration value in the earth's crust, however when compared to the average Cd concentration contained in the soil based on Mc Bride, 1994, the sampling points of 4 (Nanjung), 5 (Cisirung), 6 (Dayeuhkolot), 7 (Ciheulang), 8 (Wangisagara), and 15 (Cisanti Spring) are lower than the average Cd concentration contained in soil around the world

Cr concentration in the catchment area of Saguling lake range from 59.13-160.76 mg/kg, the mean value of 110.57 mg/kg. The lowest concentration is at sampling point 6 (Dayeuhkolot) and the highest at sampling point 11 (Halimun Mountain). Cr concentration in the earth's crust is 126 mg/kg while the average Cr concentration in the earth's soil is 90 mg/kg [11,19]. Cr concentrations in

the Catchment area of Saguling lake when compared to the concentration values contained in the Earth's crust are mostly lower, there are only the five sampling points above 90 mg/kg i.e. the sampling point 10 (Pacet), 11 (Halimun Mountain), 12 (Margamukti), 16 (Cisanti Springs 3), and 19 (Guha Mountain). Cr concentration contained in Catchment area of Saguling lake is higher than that of in world's soil

Cu concentrations in catchment area of Saguling lake range from 32.60-69.16 mg/kg, the mean value 49.93 mg/kg. The lowest concentration is at sampling point 16 (Cisanti Springs 3) and the highest at sampling point 6 (Dayeuh Kolot). Cu concentration in the earth's crust is 25 mg/kg while the average Cu concentration in the earth's soil is 45 mg/kg [11,19]. Pb concentrations in Catchment area of Saguling lake range from 3.80-43.63 mg/kg, the mean value 18.62 mg/kg. The lowest concentration is at sampling point 21 (Wayang Mountain 1) and the highest at sampling point 16 (Cisanti Springs 3). The concentration of Pb in the earth's crust is 14.8 mg/kg while the mean concentration of Pb in the world's soil is 20 mg/kg [11,19]. Table 4 describes the statistical parameters of heavy metals stream sediment samples from the Catchment area of Saguling lake

Table 4. Statistical parameters of heavy metals streams sediment samples from the catchment area of Saguling lake expressed in mg/kg

Element	Min	Max	Mean	Median	St Dev
Cd	0.17	0.53	0.34	0.32	0.10
Cr	59.13	160.76	110.57	107.06	28.61
Cu	32.60	69.16	49.93	49.81	9.28
Pb	3.80	43.63	18.62	16.18	9.83

Table 5 describes the Cbg of some heavy metals from various sources.

Table 5. Cbg of element in sediment expressed in mg/kg

Area	Element			
	Cd	Cr	Cu	Pb
Crust [(a)]	0.1	126	25	14.8
World Average[(b)]	0,3	90	45	20
River Sediment[(c)]	1.26	62.1	11.5	57.8
Range in soil [(d)]	0.06-1.1	7-221	6-80	10-84
River Sediment[(e)]	0.66 ± 0.69	nd	49.3 ± 39.3	7.3 ± 9.6
River Sediment[(f)]	0.075	145	11.9	10.8
River Sediment[(g)]	0.42	94.90	90.10	38.10
River Sediment[(h)]	0.65	11.75	9.58	17.78
This study	0.34 ± 0.10	110.57 ± 28.61	49.93 ± 9.28	18.62 ± 9.83

[a][19], [b][11], [c][15], [d][6], [e][4], [f][5], [g][3], [h][14]

Based on literature of similar research, the value of Cbg at the site of research was determined by using the average value from the research location [18], and using the minimum concentration value [8]. In this research, the value of Cbg is determined using the average metal concentration values from 22 sampling points referring to the study of [18] because the value is not much different to the value of metal concentration contained in the earth's crust and in the world's soil. Table 6 describes summary of research on quality assessment related to heavy metal contamination in several countries.

Table 6. Summary of research on quality assessment related to heavy metal contamination in several countries

Parameters	Reference		
	[18]	[8]	This study
Research site	Turkey's Upper Tigris River	Lake Veeranam, India	Lake Saguling West Java Province
Types of metal	As, Cd, Co, Cr, Cu, Ni, Pb, Zn	Cd, Cr, Cu, Ni, Pb, and Zn	Cd, Cr, Cu, Pb
Number of sampling points	6	28	22
The method of determining Cbg	Cbg using the average value of heavy metal concentration in uncontaminated sediments	Cbg based on the minimum concentration at the site of the research.	Cbg using the average value of heavy metal concentration in uncontaminated sediments.

Based on the comparison of Cbg referring to [8,12,18,19], the Cbg in Catchment area of Saguling lake takes the average value of results since it is not much different to the Cbg in the earth's crust and the average value in the world. The results of the analysis showed that the Cbg specifically: Cd 0.34 ± 0.10 mg/kg, Cr 110.57 ± 28.61 mg/kg, Cu 49.93 ± 9.28 mg/kg, Pb 18.62 ± 9.83 mg/kg.

3.3 Application of Cbg

Heavy metals in waters usually exist in low concentrations however the anthropogenic activity will increase their concentration, and cause problems to the waters. The sediment layer is an important part for tracking various pollutants such as heavy metals. The sediment layer can act as a source of pollutants in water body and potential to release heavy metals and other pollutants from their sedimentary bonds into the water column [20]. The water pollution level by heavy metals can be estimated by analyzing the concentrations of heavy metals present in water, sediments and aquatic organisms [2].

Concentrations of heavy metals contained in Saguling Lake sediment are presented in Table 7. The results of analysis showed that Cd concentration ranges from 13.22 to 23.2 mg/kg, Cr ranges from 95.85-197.98 mg/kg, Cu ranges from 37.94-152.53 mg/kg, and Pb Ranges from 20.31-32.74 mg/kg.

Table 7. Concentrations of heavy metal in Saguling lake (mg/kg)

Location Sampling	Cd	Cr	Cu	Pb
1A	23.25	197.98	63.32	23.79
1B	22.92	184.39	152.53	25.79
2	20.92	160.10	135.35	29.11
3	20.62	169.78	64.96	20.31
4	22.90	191.02	87.25	32.74
5	22.00	174.25	82.92	28.92
6	19.15	157.97	132.80	27.9
7	20.61	189.56	83.04	25.18
8	18.64	152.16	73.36	21.18
9	19.81	163.75	126.71	26.27
10A	13.22	95.85	37.94	31.31
10B	14.58	107.82	42.89	28.29
Average	19.89	162.05	90.26	26.73
Maximum	23.25	197.98	152.53	32.74
Minimum	13.22	95.85	37.94	20.31
Standard *	1.50	80.00	65.00	50.00

* ANZECC ISQG-Low, 1997

The calculation of sediment quality applied the (CF) using Cbg based on the result of this research, specifically: Cd: 0.34±0.10 mg/kg, Cr: 110.57 ± 28.61 mg/kg, Cu: 49.93 ± 9.28 mg/kg, Pb: 18.62 ± 9.83 mg/kg. The results of calculation on sediment quality in Saguling lake are presented in Table 8. The table shows that the sediment has been contaminated by Cd at very high category, contaminated by Cr at moderate category, contaminated by Cu at moderate-considerable category, lastly contaminated by Pb at moderate category.

Table 8. Contamination Factor Category

Sampling Location	Cd	Cr	Cu	Pb
1A	Very High	Moderate	Moderated	Moderate
1B	Very High	Moderate	Considerable	Moderate
2	Very High	Moderate	Considerable	Moderate
3	Very High	Moderate	Moderate	Moderate
4	Very High	Moderate	Moderate	Moderate
5	Very High	Moderate	Moderate	Moderate
6	Very High	Moderate	Moderate	Moderate
7	Very High	Moderate	Moderate	Moderate
8	Very High	Moderate	Moderate	Moderate
9	Very High	Moderate	Moderate	Moderate
10A	Very High	Moderate	Moderate	Moderate
10B	Very High	Moderate	Moderate	Moderate

4 Conclusion

Based on the results of the analysis, the Cbg of this study are: Cd 0.34±0.10 mg/kg, Cr 110.57±28.61 mg/kg, Cu 49.93±9.28 mg/kg, Pb 18.62±9.83 mg/kg. The values of Cbg are determined to assess the sediment quality of Saguling Basin by applying the CF method. Based on the CF category, the sediment has been contaminated by Cd at very high category, contaminated by Cr at moderate category, contaminated by Cu at moderate-considerable category, lastly contaminated by Pb at moderate category.

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