Asian Journal of Fisheries and Aquatic Research

6(4): 1-9, 2020; Article no.AJFAR.57055
ISSN: 2582-3760

Distribution of Heavy Metal Lead (Pb) in Water and Plankton on Floating Net Cage Area with Different Density at Cirata Reservoir, West Java

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Authors' contributions

This work was carried out in collaboration among all authors. Author DAP designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors ZH and IMA managed the analyses of the study. Author HH managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJFAR/2020/v6i430101
Editor(s):
(1) Dr. Luis Enrique Ibarra Morales, University of Sonora, Mexico.
Reviewers:
(1) Patricio De los Ríos-Escalante, Universidad Católica de Temuco, Chile.
(2) Hênio do Nascimento de Melo Júnior, Universidade Regional do Cariri, Brazil.
(3) Julyus Melvin Mobilik, Malaysia.
Complete Peer review History: http://www.sdiarticle4.com/review-history/57055

Original Research Article

Received 15 March 2020
Accepted 21 May 2020
Published 30 May 2020

ABSTRACT

Cirata Reservoir mostly functions as a Hydroelectric Power Plant (PLTA) and the location of fish farming with the floating cage system (KJA). Utilization of reservoirs for fish culture in Cirata Reservoir has exceeded the capacity determined by the government. This causes changes in water quality in the waters of the Cirata Reservoir and affects the concentration of heavy metal lead in the waters. The purpose of this study was to determine the distribution of heavy metal lead (Pb) that exist in the KJA with different densities in the Cirata Reservoir. This research was conducted on 3 November-8 December 2019 at Cirata Reservoir with sampling stations in Jangari, Maleber and Patokbeusi. The method used in this research is purposive sampling. The results of the physical-chemical parameter research show that the water temperature at the three stations ranges from 31.9°C-34.5°C, air temperature 27°C-32°C, transparency 53.5-76 cm, pH 6.87-7.67, CO_2 8,4-16.8 mg/L, BOD 1.1-20.5 mg/L and DO 5.83-9.72 mg/L. The results of Pb measurements in water ranges from 0,001 to 0,029 mg/L. Pb measurements in plankton ranges

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from 0.001 to 0.039 mg/L. Pb bioconcentration factor values range from 1.27 - 2.40. These results indicate that aquatic organisms in the Cirata Reservoir can accumulate metals in their bodies.

Keywords: Cirata reservoir; lead (Pb); plankton; water quality.

1. INTRODUCTION

Cirata Reservoir is a cascade type reservoir that is in one river flow there are more than one reservoir. Cirata Reservoir is a cascade type flow whose water comes from the Citarum river along with two other reservoirs namely the Saguling Reservoir (upstream) and Jatiluhur (downstream). Cirata Reservoir has a very useful potential to meet the needs of the community, namely as a Java-Bali hydroelectric power plant, a supplier of raw water needs, irrigation, tourism and communication, floating net cage aquaculture and capture fisheries [1].

The development of fish farming in the Cirata Reservoir is very rapid. In 2016 the number of KJA (Keramba Jaring Apung/Floating Net Cage) reached 77,000 and in 2018 the number of KJA in the Cirata Reservoir reached around 98,397 plots [2]. The large number of KJA has made the government make efforts to limit the number of KJA. The government through the Citarum Harum Task Force has curbed 10,777 KJA in the Cirata Reservoir [2]. If the limitation on the number of floating net units in Cirata is based on the carrying capacity of the waters, it is suspected that there has been an excess of floating net cages in the Cirata Reservoir [3].

Pollution of reservoir ecosystems by heavy metals at certain concentrations can cause various ecological disturbances in the aquatic environment. This pollution problem can have a destructive impact on fisheries biodiversity and fisheries productivity [4]. The concentration of lead heavy metal (Pb) in water in the Cirata Reservoir has exceeded the established quality standards. The high concentration of lead is thought to come from waste discharges from domestic and industrial activities into the waters and comes from the battery industry, motor vehicle fuel, cable materials, electric fuses, ammunition, solder and the printing industry (ink) as well as from power plants that use materials fossil fuel [5]. Furthermore, the biggest Pb usage occurs in battery production and for additives to improve the quality of gasoline. The concentration of Pb in water in the Cirata Reservoir exceeds the established quality standards [6].

The decline in water quality in the Cirata Reservoir can have a negative impact on those who utilize the Cirata Reservoir, especially the KJA cultivators themselves. Therefore, research is needed on the distribution of lead heavy metals (Pb) to determine / map the distribution of lead heavy metals (Pb) that exist in the KJA with different densities in the Cirata Reservoir.

2. MATERIALS AND METHODS

2.1 Research Location

This research was conducted in the Cirata Reservoir, West Java. The study was conducted by a survey method using a purposive sampling technique. This research was conducted at the transition of the dry season to the rainy season, namely on November 3 - December 8, 2019. The determination of the station is based on different KJA densities. Sampling locations are in three KJA blocks in the Cirata Reservoir, West Java, Indonesia, namely in the Jangari block with a total of 3,584 plots of KJA, 2,075 plots of Meleber block, and 2,268 plots of Patokbeusi block [7].

2.2 Sampling and Measurement

Data is taken for 6 repetitions at each station. The location of the research location can be seen in Fig. 1. One liter of water from the KJA area is taken and put into 330 ml sample bottle. Measurement of water physical variables including temperature and transparency as well as chemical variables including DO and pH are carried out directly at the research location while the measurement of chemical variables namely CO_2 and BOD are carried out at the FPIK UNPAD SDP Laboratory and Pb sample measurements are carried out at the UNPAD Central Laboratory can be seen in Table 1.

2.3 The Sampling of Heavy Metal Lead (Pb) Sample

Pb metal sampling stage consists of samples taken in the KJA area by filtering as much as 5 L using a plankton net with a mesh size of 20 µm. Then put into a cool box containing ice cubes as a temporary preservative before being analyzed in the laboratory. Subsequently, the samples were taken to the UNPAD Central Laboratory to be prepared and analyzed using an Atomic Absorption Spectrophotometer. The principle of AAS refers to the Indonesian National Standardization Agency in 2011 is that the Pb element atoms interact with light from the Pb lamp. The interaction in the form of light can be seen on the AAS display (monitor).

2.4 Data Analysis

The results of the measurement of Pb heavy metals in water and plankton samples were analyzed descriptively and comparatively descriptive. The Pb metal concentration of water samples is compared with the quality standard value of PP RI No. 82 of 2001 class 3 [8]. Pb metal concentrations in plankton samples are compared with the Canadian Environmental Quality Guidelines (1999) because in Indonesia there is no standard Pb concentration in plankton that can be referenced. In addition, to determine the level of organism's ability to accumulate Pb metals that enter the body, bioconcentration factor calculations are performed.

2.4.1 Bioconcentration factor

According to Conell and Miller (1995) bioconcentration factors are calculated using the following formula [9].

$$C_B = \frac{K_B}{C_W}$$

Information:

C_B = bioconcentration factor
K_B = concentration of heavy metals in biota
C_W = concentration of heavy metals in water

2.4.2 The determination of heavy metal concentration of water samples

Determination of heavy metal concentrations by direct method is for water samples and dry method (ashing) is for solid / sediment samples. The measurement of heavy metals using AAS (atomic absorption spectrophotometry) referring to the Indonesian National Standardization Agency in 2009 calculated with the following formula.

$$Heavy\ metal\ (ppm) = \frac{[(\mathrm{Ac} - \mathrm{Ab}) - a]x100}{\mathrm{bxW\ (gr)x1000}}$$

Information:

Ac = Absorbance example
Ab = Absorbance blanka
a = The intercept of the standard regression equation
b = The slope of the standard regression equation
W = sample weight (g)

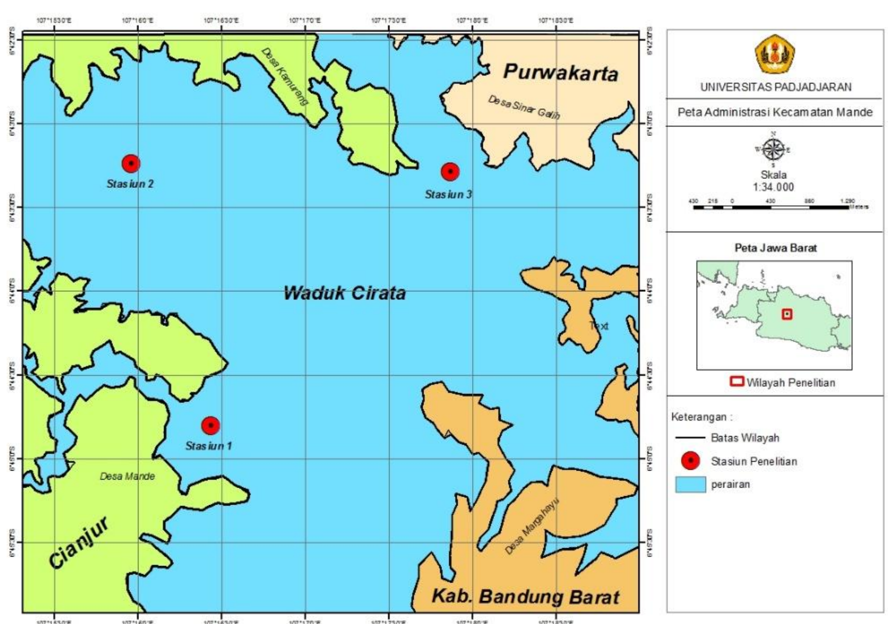

Fig. 1. Research location map

Table 1. Water quality parameters and research analysis tools

Parameter	Unit	Methods	Location of observation
Temperature	^oC	-	Insitu
Transparency	Meter	-	Insitu
pH	-	Potentiometric	Insitu
CO_2	mg/ L	Titrimetric	Laboratory
DO	mg/L	Potentiometric	Insitu
BOD	mg/L	Iodometric	Laboratory
Pb	mg/L	AAS	Laboratory

2.4.3 Correlation of heavy metal pb in water with plankton in floating net cage with different density amounts

Pearson Product Moment Correlation, which is a parametric measurement will produce a correlation coefficient that serves to measure the strength of a linear relationship between two variables with the formula as below.

$$= \frac{n\sum XY - \sum X.\sum Y}{\sqrt{\{n\sum X^2 - (\sum X)^2\}\{n\sum Y^2 - (\sum Y)^2\}}}$$

Information:

X = Pb in Water
Y = Pb in Plankton
n = Amount of data

3. RESULTS AND DISCUSSION

3.1 Physical and Chemical Parameter of Water

The calculation of physical and chemical parameters of the waters can be seen in Table 2. The results of temperature measurements show that the average water temperature at the research location ranges from 32.9^{o}C - 33.3^{o}C. Differences in the average value at each station due to the weather during sampling; there is a transition from the dry season to the rainy season. The second test of the water temperature tends to be low due to cold weather conditions and little solar radiation while the first test tends to be high because the weather is hot, so the water temperature increases.

The high temperature in the waters will cause the toxicity of a heavy metal increase because when the water temperature rises, it will cause a decrease in dissolved oxygen levels. Environmental conditions when lacking oxygen will cause lead metals to be reduced to divalent Pb (Pb2 +) and more dangerous than tetravalent Pb (Pb4 +) [10].

The results of measurements of the average air temperature in the research location ranges from 30.0^{o}C - 31.0^{o}C. In general, the temperature gives an indication of the influence on the level of productivity of aquaculture activities in the Cirata Reservoir.

The average transparency measurement results range from 59.2 - 66.8 cm. The difference is caused by the different intensity of sunlight entering the waters. Transparency is greatly influenced by weather conditions, measurement times, turbidity and suspended solids [11]. Then there is a change in the season when research becomes another factor in the difference in the value of transparency. The highest transparency value at station 2 on the second test was 75 cm and the lowest at station 3 on the first test was 38.5 cm. Water conditions that are transparent and low too high will reduce plankton abundance, this is because the decrease in transparency will cause food for plankton to be reduced, as well as the negative phototactic nature of plankton that is moving away from the light source [12]. The low value of water transparency is thought to be due to the high concentration of suspended organic and inorganic material, plankton density, microorganisms and detritus [13].

The results of pH measurements during observation ranged from 6.8 to 8.7. The pH value at station 3 is relatively higher compared to station 1 because the pH condition is closely related to carbon dioxide if the pH is higher the lower the carbon dioxide level [14]. The optimum pH for plankton life is 6.0 - 8.0 and based on observations of Cirata Reservoir waters is very supportive for plankton life [15].

Table 2. Physical and chemical parameters of Cirata reservoir waters

Parameter		Station		
		1	2	3
Water Temperature (°C)	Average	32,9±0,91	33,1±0,43	33,3±1,42
	Range	32-34,5	32,8-34	31,7-35
Air Temperature (°C)	Average	30±1,26	31±1,17	30±1,77
	Range	28-32	28,5-31,5	27-31,5
Light Transparency (cm)	Average	62,3±2,86	66,8±4,73	59,2±11,27
	Range	58,5-62	61,5-75	38,5-67
pH	Average	7,2±0,30	7,2±0,36	7,5±0,68
	Range	6,8-7,5	6,9-7,8	7-8,7
CO_2 (mg/L)	Average	11,2±2,16	13,3±1,71	11,9±1,71
	Range	8,4-12,6	12,6-16,8	8,4-12,6
BOD_5 (mg/L)	Average	7,2±6,93	8,3±3,92	7,2±6,48
	Range	2-20,5	2,2-13,5	2-17,5
DO (mg/L)	Average	8,6±1,07	8,7±1,19	8±1,31
	Range	6,8-9,7	7,1-9,7	5,8-9,1

The results of CO_2 measurements at each station ranges from 8.4-16.8 mg/L. The highest average CO_2 value is at station 2 which is 13.3 mg/L and the lowest is at station 1 which is 11.2 mg/L. High or low CO_2 concentration is thought to be due to the influence by the decomposition and oxidation of organic compounds by microorganisms contained in polluted water [16].

BOD measurement results in the three stations ranges from 2.0-20.5 mg/L. The low BOD value on the fourth repetition is due to a change in season from dry to rainy season, causing the water level to increase, but the amount of organic material is the same as the previous week because the dilution process has not yet occurred intensively. Whereas, the high value of BOD on the sixth repetition is caused by the input of organic matter carried by the flow of water and rain so that organic material increases. This happens intensively because it has entered the rainy season. According to PP RI No. 82 of 2001, BOD concentrations at each station generally passed the quality standards in class II and class III, which are 3 mg/L and 6 mg/L, which mean that it is not good for fishing activities.

Dissolved oxygen measurement results based on observations ranges from 5.8 to 9.7 mg/L. DO concentration is influenced by the process of oxygen diffusion found in the atmosphere and photosynthetic activity by aquatic plants and phytoplankton [9]. If based on PP No. 82 of 2001, the DO concentrations at each station included in class II and III because they exceede the minimum concentration of 4 mg/L and 3 mg/L.

Table 3. Rainfall data for November-December 2019

Date	RR	Date	RR
03/11/2019	**15,5**	**17/11/2019**	**0**
04/11/2019	31,2	18/11/2019	0
05/11/2019	3,2	19/11/2019	0
06/11/2019	10,8	20/11/2019	0,2
07/11/2019	19,2	21/11/2019	31
08/11/2019	2,2	22/11/2019	5,7
09/11/2019	5,6	23/11/2019	6,6
10/11/2019	**0,2**	**24/11/2019**	**0,6**
11/11/2019	14,7	25/11/2019	13,8
12/11/2019	6,3	26/11/2019	20,3
13/11/2019	0	27/11/2019	16,6
14/11/2019	3,5	28/11/2019	8888
15/11/2019	0	29/11/2019	0,2
16/11/2019	0	30/11/2019	0

Date	RR
01/12/2019	**0,8**
02/12/2019	0,2
03/12/2019	8888
04/12/2019	13
05/12/2019	14,6
06/12/2019	0,2
07/12/2019	12,2
08/12/2019	**9,2**

Information:

8888: data is not measurable
9999: no data (no measurement)
RR: rainfall (mm)
Bold: research date

3.2 Heavy Metal (Pb) Concentration in Water

Pb metals that enter the waters as a result of human activities, including wastewater from industries related to Pb metals such as the paint industry, batteries, and electronic goods [17]. Besides activities in the Cirata Reservoir environment such as KJA, boat transportation can be a contributor to Pb metal in the waters [18]. Pb metal concentrations in water can be seen in Table 3.

Pb heavy metal concentrations in water ranges from ≤ 0.001 to 0.029 mg/L, based on an average value below the threshold set by PP RI No. 82 of 2001 amounted to 0.03 mg/L.

The highest concentration of heavy metal Pb in water is at station 1 at repetition 4 at 0.0291 mg/l and the lowest at the three stations at repetition one to three that is ≤ 0.001 mg/l.

All stations on one to three repetitions have a concentration value of ≤0,001 mg/l. That is because the sampling is done during the dry season which causes the Pb metal concentration to be undetectable. The dry season causes the metals in the waters to settle to the bottom because there is no stirring of the water mass. Meanwhile, in the rainy season, mud which is at the bottom of the waters will be stirred and form a sediment. Besides the content of heavy metals in the sediments are much higher than in the water, as well as the nature of the heavy metal is bound with the dissolved material will react and bind heavy metal cations eventually settle and unite with sediment [19]. In addition, Cirata Reservoir experiencing a very significant decrease in water level, as far as 17 m, is another factor [20].

The low concentration of Pb metal in water at station 2 is also thought to be caused by the large number of scattered water hyacinths (*Eichornia crassipes*). Water hyacinth can absorb and accumulate heavy metals in the root and leaf tissues and has a certain mechanism to accumulate metals in certain organs such as roots [10]. *Eichornia crassipes* was able to lower the heavy metals Pb in free waters, is also capable of removing heavy metals Pb concentration in experimental media [21]. One of the efforts to use water hyacinth (*Eichornia crassipes*) in the Cirata Reservoir by making fish feed, organic fertilizer for agriculture, bio briquettes, arts and crafts paper [3].

3.3 Pb Heavy Metal Concentration in Plankton

Heavy metal concentrations in water bodies will rise slowly due to human activities, causing heavy metals to accumulate and can damage organs and tissues present in the body of organisms that are contaminated in the environment [11].

The results of measurements of the concentration of heavy metals Pb in plankton ranges from 0.001 to 0.038 mg/l. The concentration of Pb heavy metals in plankton at each observation has varying values. The highest value is at station 1 at repletion 5 about 0.039 mg/l and the lowest at station 3 at repetition 3 that is around 0.001 mg/l. The concentration of heavy metals Pb in plankton is

Table 4. Lead heavy metal (Pb) concentration in water

Pb concentration in water (mg/L)	Station			Reference Government of the Republic of Indonesia Regulation No. 82 in 2001 (class 3)
	1	2	3	
Average	0,02± 0,014	0,01± 0,006	0,01± 0,010	0,03 mg/L
Range	0,001-0,029	0,001-0,017	0,001-0,022	

higher than the concentration of heavy metals Pb in water. Pb levels in plankton are higher than metal concentrations in water [16]. The results of the analysis of the concentration of Pb in plankton can be seen in Table 4.

Pb heavy metal concentrations for plankton samples at station I have an average value higher than other stations that is equal to 0.030 mg/l; it is because at this station, the Pb metal concentration in the water also has the highest value from other stations. Plankton can accumulate heavy metals in water, if the concentration of heavy metals in water is high then plankton will accumulate such heavy metals in high amounts too. This condition means that the concentration of heavy metal Pb in plankton follows the concentration of heavy metal Pb in water [22]. The average concentration of Pb heavy metals at all stations has exceeded the safety limit determined for the safety of aquatic biota life according to the Canadian Environmental Guidelines (1999) of 10 μgPb/L = 0.01 mg/L.

The existence of policies regarding the replacement of ship fuel from Solar to Pertalite has been proven to reduce the concentration of heavy metals Pb. Pertalite does not contain lead so the hydrocarbon (HC) exhaust emission content is lower than Premium or Solar [23]. In addition, the government rolled out the program "Citarum Harum" in February 2018 is another factor in helping to reduce waste, especially heavy metals.

3.4 The Correlation of Heavy Metal Pb in Water with Plankton in Floating Net Cage with Different Density Amounts

The correlation used is the Pearson Product Moment Correlation, which is a parametric measurement that will produce a correlation coefficient that serves to measure the strength of a linear relationship between two variables.

To facilitate the interpretation of the strength of the relationship between the two variables there are the following criteria.

- 0 : there is no correlation between the two variables
- >0 – 0,20 : correlation is very weak
- >0,20 – 0,40 : enough correlation
- >0,40 – 0,70 : correlation is quite strong
- >0,70 – 0,99 : correlation is very strong
- 1 : perfect correlation

Based on the calculation results obtained that the coefficient of heavy metal Pb in water with plankton in the KJA with different amounts is 0.444. Based on the decision criteria, it can be concluded that the correlation between the two variables is significant because the significance is smaller than 0.05. The correlation that occurs is positive, meaning that if the KJA with a different amount increases, it will be accompanied by an increase in the heavy metal Pb in water with plankton, the correlation that occurs is in the category of quite strong.

3.5 Pb Heavy Metal Bioconcentration in Plankton

Bioconcentration is a condition of increased concentration of pollutants in the environment. BCF (Bioconcentration Factor) calculations are performed to determine the level of organism's ability to accumulate Pb metal that enters its body. BCF values of heavy metals Pb in plankton have varying values. The BCF value can be seen in Fig. 2.

Bioaccumulation in aquatic organisms is generally influenced by the content of heavy metals in water, feed, fish species, excretion and metabolism. The presence of Pb metal in the body often replaces essential metals in enzyme work activities and is inhibiting the work of enzymes [24].

The ability of body organs to accumulate heavy metals is determined by the value of the concentration factor index (IFK) or BCF value. The higher the value of BCF in an organism indicates the higher the organism accumulates heavy metals. Based on the BCF value category according to Suprapti [25] classifying pollutant properties into three sequences, namely: highly accumulative (BCF> 1000), moderate accumulative (BCF 100-1000) and low accumulative (BCF <100).

Based on Fig. 2 the BCF value of Pb metal in plankton is low accumulative. BCF value of Pb metal ranges from 1.27 - 2.40. BCF heavy metal Pb values range from 1.27 - 2.40. The BCF value at station 2, Maleber, has the highest value among other stations that is 2.40. This shows that plankton at station 2 can accumulate Pb heavy metals by 2.40 times the concentration of Pb heavy metals contained in water. Whereas, at station 3 namely Patokbeusi has the lowest BCF

Table 5. Lead heavy metal (Pb) concentrations in plankton

Pb Concentration in Plankton (mg/L)	Station			Reference Canadian Environmental Quality Guidelines 1999
	1	2	3	
Average	0,020± 0,014	0,010± 0,006	0,015± 0,010	0,01 mg/L
Range	0,001-0,029	0,001-0,017	0,001-0,022	

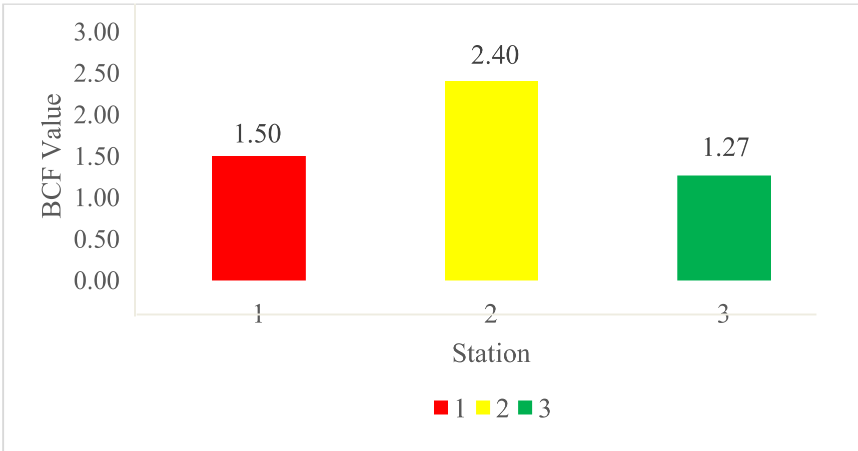

Fig. 2. BCF value of Pb heavy metal in plankton

value among other stations which is 1.27. This means that the ability of plankton in accumulating heavy metals Pb in water is 1.27 times.

The condition of the heavy metal data in water and plankton obtained is not always directly proportional, this is allegedly due to the limited reading of the metal detecting tool during the plankton sample testing. Based on BCF values, it can be said that plankton has the ability to accumulate Pb heavy metals in its body.

4. CONCLUSION

Based on the results of research conducted in floating net cages with different densities in the Cirata Reservoir, it can be concluded that the average concentration of lead heavy metals (Pb) in water samples ranges from 0.010 to 0.020 mg/L and the average concentration of heavy metals Pb in Plankton samples ranges from 0.019 to 0.030 mg/L. This value has exceeded the safe limit set by PP RI No. 82 of 2001 and the Canadian Environmental Quality Guidelines 1999. Based on the calculation of the correlation that the coefficient of heavy metal Pb in water with plankton in the KJA with different amounts is 0.444. The correlation of these two variables is significant, which is positive, which means that if the KJA with a different amount increases, it will be accompanied by an increase in Pb heavy metals in water with plankton, the correlation that occurs is in the category of strong enough. BCF value of Pb metal in plankton is low accumulative ranging from 1.27 - 2.40. Based on BCF values, it can be said that plankton can accumulate heavy metals in the body Pb.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/57055