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STUDY OF POLLUTANT LOAD ASSIMILATIVE CAPACITY AND QUALITY OF HEAVY METAL CONTAMINATION (Pb, Cd, Hg, Cu, Zn) IN SEDIMENT AND FISH IN SUNTER RIVER

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ABSTRACT

Sunter River is one of 13 rivers in DKI Jakarta. This river has a main flow along of the river about 37km in lenght. Its head water is located in East Jakarta meeting with Cipinang River and empties into the Jakarta Bay, which serves as a water flow and can not be separated from human activities. Fishes on this river are still used as food source. Nowadays, conditions of the water quality of Sunter riverwas degraded caused by various human activities occured not only in the catchment area but also along the river. This study aims to analyze the Sunter River water quality, develop the pollutant load assimilative capacity (DTBP), and reveal the level of heavy metals contamination (Pb, Cd, Hg, Cu and Zn) in sediments and fish. Determination of the status of water quality was conducted by using the STORET method, the calculation of DTBP by using Mass Balance method, the determination of contamination level of heavy metals in sediment by comparing with the quality standard of ANZECC/ARMCANZ and CCME while the level of heavy metals contamination in fish was done by comparing with the quality standard, such as ISO, BPOM, WHO and the EU regulation. This study also analyzesthe determination of bioconcentration factor (BCF) in fish. The results of this study indicate that the quality status of Sunter River generally has been severely polluted both by comparing tothe regulation No. 82/2001 and the .Governour Decree of Jakarta No. 582/1995. Meanwhile, DTBP for heavy metals in Sunter River, are i.e.0.0102-0.0329 mg /l for Pb, i.e.(- 0.0098)-0.0129 mg /l for Cd, i.e. (-0.0022)-0.0026 mg /lfor Hg, i.e. (-0.0167)-0.0254 mg /l for Cu, and (-0.0489)-0.0645 mg /l for Zn. Analysis of Pb, Cd, Hg, Cu and Zn in sediment results in the SQG-Q values of 0.87 to 1.78 indicating that the sediment surface in Sunter River are categorized as moderate impact to highly impacted potential for observing adverse biological effects to living things around it. The level of heavy metals contamination of Pb, Cd and Cu in *Clariassp*, *Anabas testudineus* and *Channa striata* has exceeded the quality standards established nationally and internationally. The BCFvalues for Hg were lower cumulative, Zn metals were generally cumulative, while Pb, Cd and Cu moderate cumulative to highly accumulative for all species of fish.

Keywords: pollutant load assimilative capacity, mass balance, heavy metals, bioconcentration factor (BCF), sunter river.

INTRODUCTION

River is a water resource with ability and capacity of water potential which can be exploited by human activities, both for social and economic activities. According to Soenarno (2001), the river as surface water is a source of fresh water widely used for agricultural irrigation, raw materials of drinking water, as the drain of rainwater and wastewater, water resources for fisheries and it has potential for tourism. Guo *et al.* (2001) states that the environmental degradation of the waters in rivers and lakes is influenced by population subsystem, subsystem of water resources, industrial subsystem, pollution subsystem, water quality subsystem, tourism subsystem, and agricultural subsystem. Human activities such as industrialization and agriculture provide a very important contribution to environmental damage and pollution, so it has a devastating effect on a body of water (river and sea) which is a necessity for life (Owa, 2014).

Sunter River is one of 13 rivers in Jakarta with ± 37 km length, flow rivers in the eastern part of Jakarta with a watershed area of 73,184,092 m^2 and the water discharge of 83.8 mm^3 which reached 100 mm^3 in a rainy season (SLHD, 2015). However, generally, rivers in Jakarta have undergone a change of water quality including SunterRiver. According to Osibanjo*et al.* (2011) the waste that goes into the body of water, either in solid and liquid form, mostly from industrial, agricultural and domestic activities.

Sunter Watershed is very densely populated which reached ± 2.5 million people in 2014. In addition, the area around the Sunter River also often suffer flood (SLHD, 2014). Fish in Sunter River are still used by local people as a source of food. In order to overcome the problem of pollution in Sunter River, it is necessary to perform integrated pollution control efforts including prevention, mitigation, and recovery.Therefore, in order to support control efforts and the prevention of pollution,this study aimed to analyze the pollution load capacity, the status of river water quality and contamination levels of heavy metals (Pb, Cd, Hg, Cu and Zn) in sediments and fish. The existence of those data was expected to provide recommendations to perform Sunter River pollution control efforts.

RESEARCH METHOD

Research area and time

This study was conducted from February to July 2016 in Sunter River where located in the administrative area of the city in East Jakarta and North Jakarta (Figure-1).

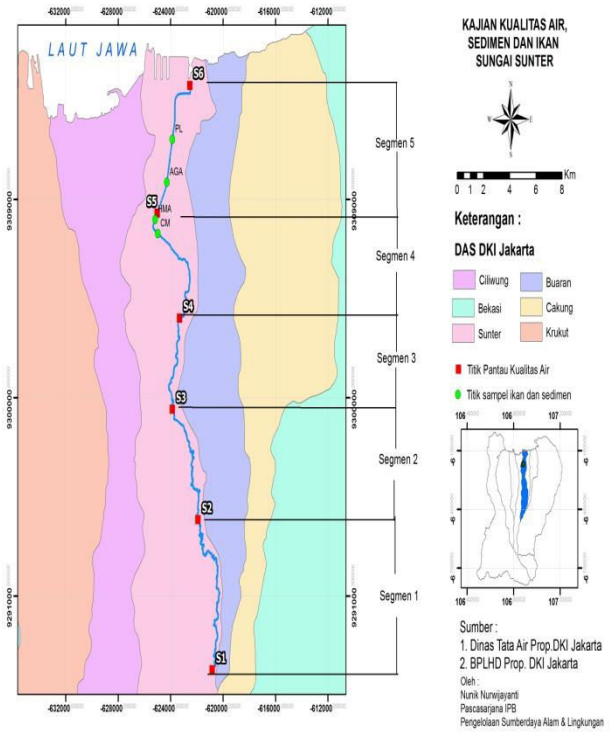

Figure-1. Map of research area.

Method of data collection

Data collection in this study was conducted by collecting samples from the field, while measurements were carried out in the laboratory.Water samples about 1L were collected from PL, AGA, CM and HMA station. The samples were added HNO_3 and pH adjusted to less than 2. Sediment samples were collected about 500g which used grab sampler and put it into glass bottle. Analysis ofheavy metals in water, sediments and fish were carried out in the laboratory of Prolink-FPIK, Bogor Agricultural University.

It was also used the secondary data to strengthen the analysis which got from BPLHD DKI Jakarta province.

Method of data analysis

Analysis of river water quality status

Determination of Water Quality Status using*STORET* Method was performed by following steps:

- Collect the of water quality data and water discharge periodically;
- Compare the measured data of each parameter with a value of water quality standards in accordance with the class of water;
- If the measurement results meet the water quality standard value (the measurement results <standard quality) then the given score was 0;
- If the measurement results do not meet water quality standards values or (measurement results> quality standards);
- The negatives number of all the parameters was calculated then its quality status determined by the number of scores obtained by using a system of values.

The scoring system and its criteria can be seen in Tables 1 and 2.

Table-1. Determination of the value system to assess the status of the environment.

Number of observation	Value	Score for each parameter (when it more than standard value)		
		Physics	Chemical	Biology
<10	Maximum	-1	-2	-3
	Minimum	-1	-2	-3
	Average	-3	-6	-9
≥10	Maximum	-2	-4	-6
	Minimum	-2	-4	-6
	Average	-16	-12	-18

Table-2. Determination water quality.

Total score	Quality level	Class	Note
0	Very good	A	Good Water Quality
-1 s/d -10	Good	B	Lightly polluted
-11 s/d -30	Medium	C	Moderately polluted
< -30	Bad	D	Heavily polluted

Source: Ministry of Environment Decree No. 115/ 2003

Analysis of pollutant load capacity

In this current study, inorganic pollutant loads were calculated by using the mass balance method in accordance with the Ministry of Environment Decree No. 110/2003 on Guidelines for Determining Load Capacity of Water Pollution in Water Resources. The mathematical models used a mass balance calculation can be used to determine the average concentration of downstream site which came from point sources of pollutant and non-point sources. This calculation can be applied to determine the percentage change in flow rate or pollutant load. If multiple streams meet to produce a final stream, or if the quantity of water and constituent mass is calculated separately, it is necessary to perform mass balance analysis to determine the quality of the final flow by following calculation :

$$CR = \frac{\sum Ci\,Qi}{\sum Qi} = \frac{\sum Mi}{\sum Qi}$$

Where
CR :average concentration of combined flow constituents
Ci : constituents concentration for i-flow
Qi : Discharge of i-flow
Mi : contituents mass for i-flow

The mass balance method can also be used to determine the effects of erosion on water quality that occurs during construction or operational phase of a project. Moreover, it can also be used for a stream segment, a cell in the lakes and oceans. However, the weight scale method is only appropriate for the conservative components or a component that does not change (not degraded, not lost during precipitation and evaporation, or other activities) during the mixing process, such as the salts.

Analysis of heavy metal contamination in sediments

The results of the measurement of heavy metals Pb, Cd, Hg, Cu and Zn in sediments was compared with the quality guidelines of ANZECC / ARMCANZ (2000) and the CCME (1999). The use of that guidline because Indonesia does not have sediment quality guidelines yet (Lestari and Budiyanto, 2013). Subsequently, the comparison of the analysis of heavy metals in sediment was conducted by using the guidelines Sediment Quality Guidelines (SQGs). Sediment quality index in this study area used sediment quality guidelines (Sediment Quality Guidelines Quotion, SQG-Q) (MacDonald *et al*., 1996), based on the following formulas:

$$PEL - Qi = \frac{\text{contaminant}}{PEL}$$

$$\text{SQG} - \text{Q} = \frac{\sum_{i=n}^{n} PEL - Qi}{n}$$

PEL-Qi is calculation results of contaminant concentrations that measured by its PEL value, then the number of several contaminants parameters tested were summed and divided by the number of contaminants types tested then the value of SQG-Q obtained. The values were then categorized into several classes as shown in Table-3.

Table-3. Category of SQG-Q.

Class	Category
SQG-Q<1	**unimpacted**, lowest potential for observing adverse biological effects
0,1< SQG-Q<1	**moderate** impact potential for observing adverse biological effects
SQG-Q ≥ 1	**highly** impacted potential for observing adverse biological effects

Analysis of heavy metal contamination in fish

In this study, the determination of residues or contamination of heavy metals Pb, Cd, Hg, Cu, and Zn in fish used Atomic Absorption Spectrophotometer (AAS) (Priyanto *et al*. 2008). The content of heavy metal contamination in fish was compared to the quality standards of the national standard of Indonesia National Agency of Drug and Food Control (BPOM) year 2009 and ISO 7387 in 2009. Limit of Heavy Metal Contamination in Food and international standards Commission Regulation (EC) No.1881 / 2006 *setting Maximum Levels for Certain contaminants in Foodstuffs*, According to Lamai *et al.* (2005) in Budiati *et al*. (2014), a method for evaluating the potential of metals-absorbing organisms by calculating the bioconcentration factor (Bio Concentration Factor / BCF) based on the following formula:

$$BCF = \frac{C\ fish}{C\ water}$$

C fish = the concentration of heavy metals in fish (mg/kg or ppm)

Cwater = the concentration of heavy metals in water (ppm)

RESULTS AND DISCUSSIONS

Quality status of Sunter River

Calculation of Sunter river quality status in the period 2012 - 2015 was compared to the quality standards of Government regulation No. 82/2001 and Jakarta Governor Decree No. 582/1995 to determine the percentage difference of Sunter river status at each point observation. Figure-2 shows the calculation results of Sunter river quality status determination by comparing the standard class II and class III which is set in government regulation No.82 / 2001.

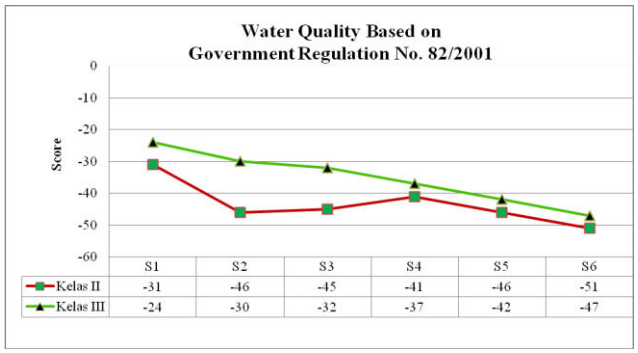

Figure-2. Graph of quality status based on government regulation (PP) No.82/2001.

The determination results of the quality status indicated that based on comparison to the standard class II, according to the criteria listed in Table 1, water quality of Sunter River was heavily polluted at all observation station. However, when it compared to the standard class III in station S1 and S2, the category still being polluted with moderately polluted level. The parameters caused the quality status of Sunter River being heavily polluted were BOD, COD, Phosphate, and Pb. According to the comparison of standard class III, the station S1and S2 are possible as a source of water for fisheries, livestock and to irrigate crops, so it has a potential to produce a good food product. This result is consistent with the statement of Lasmi, (2007) that the water quality of the river is a tool that can be used to predict and evaluate an environmental change. The water quality can be categorized as the good water when it met the water needs as it pure designation, such as raw materials of drinking water, infrastructure/recreation, industry, fisheries, livestock and agriculture. Determination of quality status is one method to analyze the water quality of the river.

Furthermore, the determination of the quality status by comparing the quality standard of Jakarta Governor Decree No. 582/1995 was shown in Figure-3.

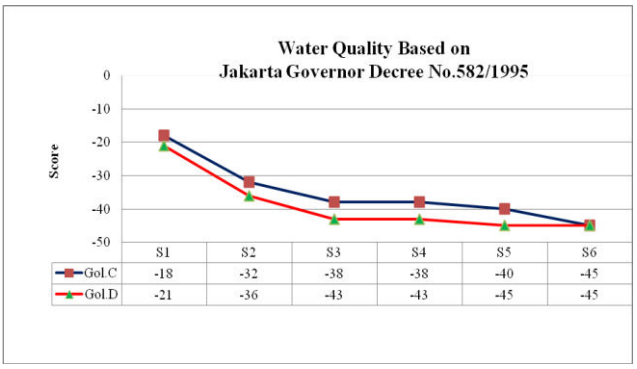

Figure-3. Graph of quality status based on governor Decree No.582/1995.

Determination of water quality status was compared to the quality standard of class C and D. Jakarta province had the rule to classify the functions of the rivers in their area. Basically, Sunter river included in class D. But in this study, Sunter River water quality was compared to the quality standard of group C. The determination to see the water quality status of Sunter River pollution. According to the criteria for determining the quality status of the river in Table-1, it revealed that the quality status of Sunter River in most observation station was heavily polluted except in station S1. Based on the determination results of the quality status in Sunter river water, the station might still be used for the aquaculture purposes, livestocks and irrigating plants at the station S1. Parameters that caused the status of Sunter River heavily polluted are mostly organic parameters (BOD, COD, and phosphate) and one of the parameters of heavy metal is Pb. Agustina *et al.* (2012) also stated that the parameters of heavy metals Pb, Cu and Zn at station 2 caused the status of Siak River in Pekanbaru was heavily polluted.

Load capacity of heavy metal contamination

Environment along Sunter River was generally densely populated areas, industrial and shopping center or mall. Analysis of heavy metal pollution capacity using mass balance method, where prior to identify the sources of pollution in each segment. Data sources of pollution in some segment of Sunter River observation was shown inTable-4.

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Table-4. Data of pollutans source in Sunter River.

Location	Pollutan source	Location	Pollutan source	Location	Pollutan source
Segment 1	Chicken slaughter house	Segment 4	Small enterprises (workshop)	Segment 5	Apartement
	Bus station		Minimarket/Mall		Hospital
Segment 2	Antam Medika Hospital		Parking area on the river bank		Kelapa gadingdepartement stores/mall
	PDAM (water supply company)		Otomotif Company		Otomotif Company
	Hospital. Persahabatan		Hospital		Food industry
Segment 3	PT. Auto Pit Sejahtera		Small enterprises (fotocopy)		PT. Pertamina (logistic)
	Mall				School
	College				

Based on the identification of pollutant sources in Table-3, the sources of these pollutants was suspected of causing high heavy metal contamination in Sunter River. This is consistent with the statement of Wittman (1979) in Connell and Miller (2006) that one of the main sources of heavy metals into the water is a liquid household waste. The amount of a big heavy metal were caused by the liquid household waste by garbage metabolic, corrosion liquid pipes (Cu, Pb, Zn and Cd). The calculation result of pollutant load capacity of heavy metals Pb, Cd, Hg, Cu and Zn with mass balance method using a standard class III on government Regulation No.82/ 2001, was shown in Figure-4.

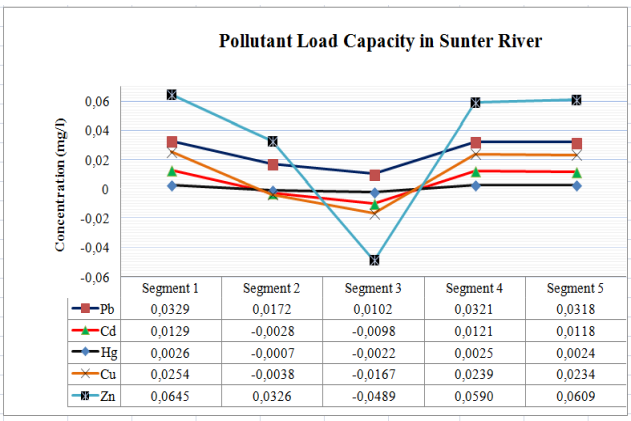

Figure-4. Graph of pollutant load capacity.

The calculation of pollutant load capacity by mass balance method shows that the maximum concentration of heavy metals that can be received by the Sunter River in each segment is different. The lowest concentration of Pb was in segment 3 of 0.0102 mg/l, and the highest in segment 1 of 0.0329 mg/l. The lowest concentration of Cd was in segment 3 of -0.0098 mg/l, and the highest was in segment 1 of 0.0129 mg/l. The lowest concentration of Hg was in segment 3 of -0.0022 mg/l, and the highest was in segment 1 of 0.0026 mg/l. The lowest concentration of Cu was in segment 3 of -0.0167 mg/l, and the highest was in segment 1of 0.0254 mg/l. The lowest concentration of Zn was in segment 3 of -0.0489 mg/l, and the highest was in segment 1 of 0.0645 mg/l. Generally the lowest concentrations of heavy metals are in segment 3, meanwhile the highest in segment 1. Mostly the pollutant load capacity in the segment 3 have negative value except for heavy metal of Pb. It means that segment 3 cannot received pollutant which contain heavy metal of Hg, Cd, Cu and Zn. The difference of heavy metal concentrations in each segment is expected due to the different amount and type of pollutant sources that exist around the segment. This proves that the maximum concentration of heavy metals that can be received by the river, especially in the Sunter River depends on the number and type of pollutant sources around the watershed. This is in accordance with the results of identification of pollutant sources in each segment. This concentration is also influenced by the flow of water in each segment. Therefore, to overcome this pollution, there needs to be controlling efforts, especially the water quality recovery efforts in Sunter River so that the water resources in the river can be used as intended.

Determination of quality of heavy metalcontamination in sediments

The result of heavy metals in water and sediment were listed in Table-5. The results showed that the concentrations of heavy metals in sediment was much greater than the concentration of heavy metals in the water, the concentration of heavy metals in sediments were generally more than 1000-fold compared with the concentration of heavy metals in the water. It proved that heavy metals are deposited in the sediments.

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Table-5. Heavy metals in water and sediment.

Location	Pb		Cd		Hg		Cu		Zn	
	Water	Sediment	Water	Sediment	Water	Sediment	Water	Sediment	Water	Sediment
PL	0,022	151,26	0,003	3,00	0,0001	0,06	0,005	93,2	1,78	440,69
AGA	0,03	159,06	0,002	3,14	0,0001	0,03	0,016	83,43	1,586	383,78
CM	0,024	192,23	0,003	4,35	0,0002	0,075	0,006	149,87	0,035	677,46
HMA	0,019	210,49	0,006	4,18	0,0001	0,135	0,01	157,62	0,123	1358,76
Average	0,024	178,26	0,0035	3,67	0,00013	0,075	0,0093	121,03	0,881	715,17

The comparison result of metal contamination quality in sediment and quality standard of ANZECC / ARMCANZ and CCME can be seen in Table-6.

Table-6. Comparison of sediment quality in Sunter river in 2016, with several quality guidelines.

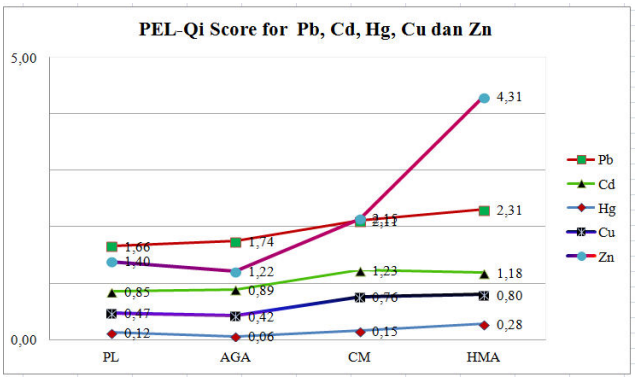
		Pb	Cd	Hg	Cu	Zn
Sunter River	Min	151,26	3,00	0,03	83,43	383,78
	Max	210,49	4,35	0,135	157,62	1358,76
	Average	178,26	3,67	0,075	121,03	715,17
ANZECC / ARMCANZ Guidelines	*Low*	50	1,5	0,15	65	200
	High	220	9,6	0,71	270	410
CCME	ISQG*	35	0,6	0,17	35,7	123
	PEL**	91,3	3,53	0,486	197	315

(*) ISQG, *Interim Sediment Quality Guidelines*
(**) PEL, *Probable Effects Levels*

The observation results indicated that the average concentration of all types of heavy metals in sediment in some locations was above the low-value of quality guidelines of ANZECC/ARMCANZ (2000), except for heavy metal of Hg which was still below the quality standard and the only Zn was above the low and high value. When it compared to the quality standard of CCME (1999), it indicated that the average concentration of heavy metals, especially Pb, Cd and Zn has been greatly exceeds the value of ISQG (Interim Sediment Quality Guidelines) and the value of PEL (Probable Effect Level), while for the average concentration of Cu has passed ISQG but still well below the PEL and only Hg was still below the type of ISQG and PEL values. Based on comparisons with the quality guidelines, types of the heavy metals were already at risk for the quality of the environment around the Sunter River and aquatic system. It should be needed to be controlled due to accumulation effect of heavy metals.

The quality of heavy metals in sediments was also compared using guidelines Sediment Quality Guidelines (SQGs). These guidelines are useful for evaluating the extent of the chemical status of sediment and negative impacts which affect aquatic organisms and it was designed to assist the interpretation of sediment quality (Wenning *et al*., 2000).

Based on the value of SQG-Q obtained with the range of 0.87 to 1.78. It showed that the sediment surface at several observation stations in Sunter River is categorized as a moderate impact on stations PL and AGA, also categorized as the potential to highly impact the adverse biological effects on stations CM and HMA. In general, the quality conditions of heavy metals in Sunter River sediment is highly impacted potential for observing adverse biological effects and living things around it (Figure-5). Similarly, it happened in the water sources of Gresik that the metals of Cd, Cu and Zn in the sediment began to give a potential risk to the quality of the environment around the aquatic system (Lestari and Budiyanto, 2013).



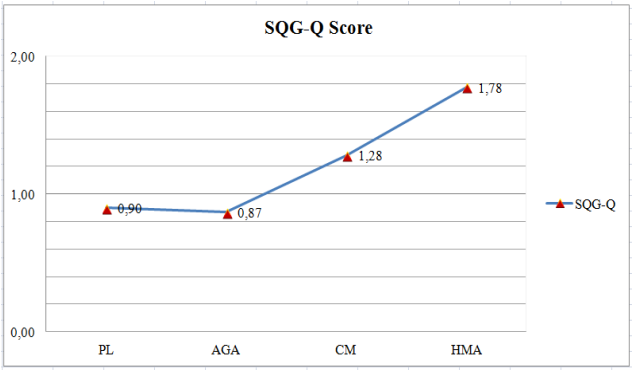


Figure-5. Graph of PEL-Qi and SQG-Q value on heavy metals Pb, Cd, Hg, Cu and Zn in sediments.

Analysis of heavy metal contamination in fish

Fish is one of the organisms that can be used as bioindicators of pollution, especially for heavy metals. Results of the determination of water quality status of Sunter River showed that almost all observation stations have been heavily polluted, but from direct observation, still many people who did fishing in Sunter River where fish obtained/catched was used for consumption. Therefore, this study also aimed to analyze the content of heavy metals in fish.

In this study, species of fish obtained were the cork (*Channa striata*), catfish (*Clarias* sp), and damselfish (*Anabas testudineus*). The local community consumed fish as a source of protein needed by the body. Result of heavy metals in fish was compared to some benchmark quality standards for food products (Table-7).

Table-7. Comparison of heavy metal polution in fish with several quality standard.

Type of fish	Pb		Cd		Hg		Cu		Zn	
	Result	Quality	Result	Quality	Result	Quality	Result	Quality	Result	Quality
Cork	24,24	SNI*) : 0,3	2,77	SNI : 0,1	0,005	SNI : 0,5	6,84	SNI: (-)	73,86	SNI: (-)
damselfish	24,12	BPOM*):0,3	2,00	BPOM: 0,1	0,004	BPOM: 0,5	4,82	BPOM: (-)	15,2	BPOM: (-)
Catfish	22,45	UE*) : 0,2	4,07	UE : 0,05	0,004	UE : 0,5	4,11	UE: 0,1	23,83	UE: (-)
damselfish	30,13	WHO**): 0,2-0,3	1,15	WHO: 0,05-0,15	0,004		6,43		18,41	
Cork	71,48		1,72		0,004		2,94		50,52	

*)SNI, BPOM, UE, mg/kg
**)WHO, mg/day

The content of heavy metal contamination of Pb and Cd in fish showed that over from the quality standards which set by Indonesia, the European Union, and WHO, however the heavy metal concentrations of Hg in fish was still below the quality standard. The quality standard for Cu only from the EU and the test results showed it already over the quality standards. Cu is a kind of heavy metals with low toxic so that Indonesia and the WHO has not set a quality standard yet. However, the quality standard for the heavy metal parameter of Zn was generally not been established. This is presumably because Zn was included heavy metals that has a low toxic properties and an essential element for animals, plants, and human. Despite an organism as bioindicators of pollution, fish was also a bioaccumulatory contaminant. According to Rahmadiani & Aunurohim (2013) in Budiarti *et al.* (2014) organisms were known as a good accumulator if they have ability to concentrate elements of heavy metals in their body tissues. Amriani *et al.* (2011) in Budiarti *et al.*(2014) BCF value has three categories, namely :

- BCF>1000 = highly accumulative
- BCF 100-1000 = moderately accumulative
- BCF<100 = lightly accumulative

Calculation results of heavy metals Bioconcentration factor in fish shown in Figure-6 revealed that the cumulative Hg was lightly accumulative for all species of fish. Zn generally was cumulative for all types of fish, especially at stations CM and HMA, meanwhile for Pb, Cd and Cu indicated the moderately to highly accumulative for all species of fish. These results were contrasts with research conducted by Miftakhul *et al.* (2014) that found the BFC of Cu on tilapia in Rawa Bening Lake categorized as moderately accumulative whereas the accumulations of Pb, Cd, and Cr were in the category of low. Based on this conditions, the value of BCF for a heavy metal type will be different depending on the location and characteristic of fish.

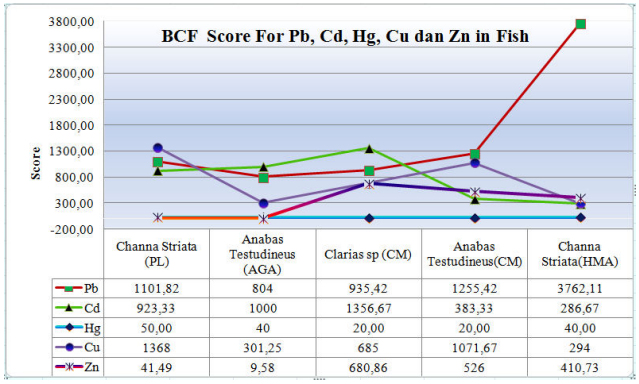


Figure-6. Graph of BCF value of heavy metals in fish.

CONCLUSIONS

Conditions of Sunter river quality status in the period 2012-2015 is generally heavily polluted in almost all observation stations, except for the determination of the quality status by using quality standards of governor decree No 582/1995 at the observation point in upstream areas which categorized as moderately polluted. Nowdays, SunterRiverdidn't have capacity to received pollutant of heavy metal especially in segment 3, which have negative value of concentration for Cd, Hg, Cu, and Zn except for Pb. The concentration of heavy metal contamination in the sediments at four observation stations was more than 1000-fold compared to those in the water. The concentration was categorized highly impacted potential for observing adverse biological effects in Sunter River. Conditions of heavy metal pollution in fish mainly for Pb and Cd, and Cu had exceeded the quality standards. BFC Values in fish of Hg was lightly cumulative, Zn metals were generally moderately accumulative, and Pb, Cd and Cu were moderately to highly cumulative for sample types of catfish, cork and damselfish.

RECOMMENDATION

Further research is expected to study the certain time and heavy metal pollution's effect on another biota. The government can use the research results related developing pollution control programs, especially for licensing firms in terms of disposal and waste management, control of household waste and small industries, and for reviewing the regulation that related to the water quality.

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