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Bioconcentration and Bioaccumulation of Chromium Heavy Metal in Small-Sclae Catfish Farming Ponds

Augita Tri Clara Shostakovich Datu Rara[1]*

[1]Department of Biology Faculty of Biotechnology, Duta Wacana Christian University

Abstract

Pollution of the Opak River by heavy metals such as chromium can have an impact on the utilization of river water for aquaculture in the Bantul Regency area. Even though this river has considerable potential in supporting the community's economy. Water contamination by harmful pollutants such as heavy metals is caused by increased human activities that produce waste. This study aims to determine the level of chromium contamination concentration in water samples, sediment and its accumulation in catfish cultivated by the community. This study also aims to find out how much BCF values in fish. The method in this study in taking sediment, water, and catfish samples is in the form of cluster random sampling method with a total of 36 samples. Testing of total chromium levels using AAS (Atomic Adsorption Spectrophotometer) instruments, while data analysis using SPSS software applications. The results of this study show that pollutants in the form of chromium metal from the Opak River have polluted and distributed into fish farming ponds through irrigation channels that are aggravated by the input of waste from the surrounding community. Chromium concentrations in water, sediment, and catfish with a range and average of 0.113-0.144 mg / L, 0.667-1.281 mg / L, and 0.258-0.434 mg / L. From the analysis that has been done it is known that the average value of BCF ranges from 1.93-3.26 mg / L which indicates that catfish have low accumulative properties

Keywords: aquaculture ponds, bioconcentration, bioaccumulation, catfish, and chromium

Introduction

Opak River which is the second largest river that has an important role in the lives of the people in Bantul Regency, Yogyakarta. In this area, there is a tanning industry center based in Piyungan District. This industry produces liquid waste which in its production uses chrome and is flowed to water bodies. This pollution is caused by the increasing growth of industry and the number of human populations (Tomno, Nzeve, Mailu, Shitanda & Waswa, 2020). Liquid waste containing heavy metals if released into the aquatic system will cause an accumulation response in the body of aquatic organisms through the food chain path (Rahardjo & Prasetyaningsih, 2017).

Most of the people living around the Opak River use water from the river to cultivate fish in soil ponds and concrete ponds. It is known that the fish that is often farmed by the surrounding community is catfish which is a type of consumable fish. In its use, the Opak River has great potential in supporting the economy as a place for the development of the aquaculture sector. This potential is very dependent on the quality of river water so that if there is a decrease in river water quality, it will indirectly affect the quality of aquaculture products.

*Corresponding Author: Augita Tri Clara Shostakovich Datu Rara, Email : augita.rara@students.ukdw.ac.id
Department of Biology Faculty of Biotechnology, Duta Wacana Christian University

One of the causes of the decline in river water quality is community and industrial activities around the river area. Waste that enters the waters can be in the form of runoff from agricultural activities that use pesticides, livestock, or domestic from feed residues and settlements (Mokaram, Saber, & Syekhi, 2020). Heavy metals that have entered and polluted one of the environmental components have the potential to pollute other components such as water, soil or other organisms.

Heavy metals are included in one of the contaminants that have toxicity properties that can result in physiological dysfunction up to death (Hidayah, Purwanto & Soeprobowati, 2014). According to Suryani et al (2018) , heavy metal content in high or low concentrations can be a trigger factor for the emergence of various diseases. On a wide scale, the ingress of heavy metals into the human body can go through several avenues, namely inhalation, food (consumption of already contaminated food), and through skin tissue. The risk posed to humans depends on the amount of dose that enters and the location where heavy metals accumulate in the body. In the aquatic environment, the effects also depend on their presence in water and sediment so that when aquatic organisms are exposed, they can cause various responses.

The results of research conducted by Rahardjo & Prasetyaningsih (2021) show that the Opak River has been polluted by the heavy metal chromium as much as 0.0004-1.1480 with an average of 0.6144 mg/Kg. Pollution to river water can become even greater if left unchecked. Research on chromium content in rivers has been carried out a lot, but there are still few who analyze the level of chromium pollution in small-scale aquaculture ponds in Bantul Regency.

Based on this description, this study aims to determine the bioconcentration of chromium metal factors in catfish as one of the community's leading aquaculture commodities, and to determine the limits of chrome heavy metals in fish that can be tolerated by the human body

Research Methods

Research design

This research was conducted in the area around the Opak River, Bantul Regency, Yogyakarta Special Region. Water, sediment, and catfish sampling was carried out in four sub-districts (Piyungan, Pleret, Jetis, and Imogiri) with one catfish farmer each taking purposive sampling. Chromium metal analysis was carried out at the Integrated Laboratory of Universitas Islam Indonesia using AAS (*Atomic Adsorpsion Spectrophotometer*) instrumentation.

Sampling

Water sampling was carried out at 4 sampling points, each of which was ±100 ml and was included in an HDPE bottle. The water samples obtained were then preserved using 1% HNO_3%. Sediment sampling was carried out at 4 sampling points of ±100 grams each using a grab sampler. The collected samples can be directly cooled to a temperature of 4°C. The catfish sampling process is carried out using a long tool and a net. The samples obtained were then rinsed with clean water and put into a cooling box and frozen at -20°C (SNI 6989.57:2008; Rajeshkumar and Li, 2018; Montes, Ferreira, Giarrizzo, Amado, & Rocha, 2020).

Sample preparation

The preparation of fish samples is carried out by calculating the total length (cm) and body weight (gr) then surgically with the help of a knife so that bones, skin and meat can be separated. After cleaning and weighing as much as 25 grams and ventilated for 8 hours. After heating in the oven, the fish meat is mashed to get 2 grams of smooth powder. The sediment sample is separated from other impurities and weighed. Then put in the oven with a temperature of 150°C to dry. Samples that have been dried are mashed and filtered to gain a weight of 2 grams

Sample extraction

Extraction of water samples is carried out by adding 10 ml of concentrated HNO3. The sample is heated to a volume of ±20 ml. The addition process is carried out twice and then filtered using Whattman Filter paper No.42 into a 50 ml measuring flask. In solid samples (sediments and fish) extraction was carried out by the acid method. Each sample is entered in erlenmeyer and added akuaregia in a ratio of 3:1, then heated to a volume of 10 ml. The process of adding akuaregia is carried out twice and the extract results are filtered into a measuring flask of 10 ml. The volume of extraction results that are less than 10 ml is added to the aqueous and homogenized.

Research Results and Discussion

Based on the results of studies that have been carried out, it shows that chrome metal levels in water, sediments, and catfish cultivated in small-scale ponds, the following results are obtained as shown in table 1 .

Accumulated chrome concentration on the sample

Accumulation of chrome in water

Based on table 1, the results of chromium heavy metal concentrations in varied water, sediment and catfish samples were obtained. The concentration of chrome heavy metals obtained ranges from 0.133-0.144 mg / L. According to Pergub DIY No.20 of 2008 concerning water quality standards of 0.05 mg / L, so that the water of aquaculture ponds in 4 sub-districts does not meet the standards. There is a pattern that the highest chrome concentration is at the furthest point from the pollutant source which is inversely proportional to Siaka's (2012) research which states that heavy metal levels are decreasing as the distance from the source of pollution increases. The increase in chrome levels that occurs is caused by the input of waste from domestic waste into aquaculture ponds that tend to stagnate so that an increase in chrome concentration figures cannot be avoided. The concentration of chromium in the water at the imogiri sampling station is much higher compared to the piyungan station. Such results are influenced by water changes and aeration in cultivated ponds. Based on Astuti and Pratiwi (2016) stated that microbes use a lot of oxygen to decompose organic matter so that an aeration system is applied to increase oxygen so that the decomposition process can run properly. At Imogiri station, catfish farming ponds tend to stagnate so that there is no change of water so that the chrome contained in the water is much more accommodated. Meanwhile, at the piyungan station, there are periodic changes of water and aeration which causes the potential for chrome in the water to tend to be small because it is carried away by the flow of water.

Accumulation of chrome in sediment

The results of measuring chromium concentrations in sediment samples from each catfish farming pond ranged from 0.667-1.281 mg / L. According to WHO / FAO (2001) determined that the tolerance limit of chromium contamination levels in sediments was 20 mg / L so that the chromium concentration in sediment samples in each cultivation pond still met the quality standards. There are several factors that influence the increase and decrease in chrome concentration in sediments, namely the presence of chrome deposition carried by water from domestic sewage runoff as well as from river water. In addition, there are other influencing factors, namely the presence of turbulence in the sediment caused by the currents (Mauna, Ma'rufi, & Nigrum, 2017). This shows that the concentration of chromium in sediments is much higher than the concentration of chromium in pond water. This can happen because one of the characteristics of chromium tends to be easily deposited at the bottom of the waters so that the content of heavy metals in sediments is much higher than water (Nuraini *et al*., 2017; Rumoey *et al.,* 2022). In addition, chrome is categorized as a contaminant material that is always present in the environment because it is a natural component that has persistent and toxic characteristics so that its presence in an environment with an excess dose will have a negative impact (Kurniawati, Nurjazuli, & Raharjo, 2017).

Accumulation of chrome in catfish

The diverse aquatic organisms that exist can be differentiated into various categories depending on their ability to integrate the effects of pollutants so as to be a reflection of habitat quality (Abdelkarim, 2020). Fish belongs to one of the aquatic organisms that can be used as a bioindicator to monitor the environmental conditions of the waters. This is because fish have sensitivity to changes that occur in their habitat (Sitompul, Barus & Ilyas, 2013). In the samples of cultivated catfish, the results were obtained that in the meat accumulated chrome metal that has varying values. In table 1, it can be seen that the chrome concentration ranges from 0.258-0.434 mg/L. So when compared with the BPOM quality standard No. 03725 / B / SK / 89 which requires a tolerance limit of heavy metal contamination in foodstuffs of 2.5 ppm, the chrome concentration in catfish meat samples still meets the quality standards. But such a thing needs to be considered again to consume fish meat contaminated with chrome. According to Rajeshkumar and Li (2018) the high accumulation of chrome in fish meat shows that there are traces of metal entering, but due to its persistent nature it tends to accumulate in the body. Another influential factor is the limitation of fish movement space. In their research, Haryanti et al, (2020) stated that if the fish are in an unrestricted space, then the fish can move freely because it has the ability to avoid the influence of pollution. On the other hand, if the space for fish movement is limited, it will be difficult for the fish to avoid the influence of pollution so as to give rise to an accumulation response in the body. In addition, the accumulation of metals that occur in the body of fish is caused by the absorption process of the food chain and direct exposure of water containing heavy metals (Sitompul, Barus & Ilyas, 2013).

The ability of fish organs to accumulate chrome heavy metals.

The ability of organisms to accumulate heavy metals directly from water is expressed by bioconcentration factor. The classification of the accumulation ability of an organism is based on the value of BCF by Van Esch (1997) in Hidayah et al., (2014) which classifies the properties of pollutants into three, namely: (BCF>1000) high accumulative, (BCF 100-1000) medium accumulative, and (BCF<100) low accumulative. Based on the calculation results, the value of BCF in catfish varies with a range of 1.93-3.29 L / Kg. This is influenced by several factors such as organism species, bioecology, environmental conditions and the magnitude of chrome concentrations contained in water and sediments (Raharjo et al., 2021). In addition, there are other influencing factors such as in research conducted by Kurniawati et al (2017) which shows that the size of the fish body can visualize the age of the fish so that the length of exposure will last longer than fish that have a small body size. Based on research conducted by Fitrah et al (2019) it is stated that the higher the BCF value in an organism, the organism has a high accumulative level as well. The accumulative ability of an organism is highly dependent on an environment that includes temperature, pH, and dissolved oxygen (Zainuri et al., 2011). The presence of heavy metals in the waters gives rise to an accumulation response in fish as a result of continuous exposure. According to Darmono (2008) organisms that have hydrophobic characteristics are able to carry out the accumulation mechanism directly through the gills or skin. The presence of chromium found in catfish meat cultivated from the four sub-districts that get flow from the Opak River is an indicator that aquatic animals such as farmed fish have been threatened by chrome metal contamination. Although the calculation results of BCF Cr in catfish are relatively low, they still have to be vigilant because of the characteristics of heavy metals that tend to be accumulative in the body so that if consumed continuously it will cause a chronic response (Hidayah et al., 2014).

Safety in consuming farmed catfish

Based on the test results, it was found that the concentration level of chrome in catfish meat was between 0.258-0.434 mg / L (table 2). The results of this concentration when compared with the regulations authorized by the Director General of BPOM through Decree No. 03725 / B / SK / 89 concerning the limit of metal contamination in food of 2.5 mg / kg, the chrome metal content in catfish has not exceeded the standard so that it can be said to be still safe for consumption. The level of safety of catfish meat consumption can be obtained by determining the maximum limit of metal concentration in meat consumed per week. WHO/FAO has determined that the weekly intake limit of chrome heavy metals that can be tolerated by the body is 0.15 mg/kg. The calculation data found that there is 1,398 μg / g of chrome concentration in catfish meat that can be tolerated by the human body per week (MWI). As for maximum tolerable intake (MTI) to avoid adverse effects on the body, the weight of adults per 60 kg is 5,028 mg. Thus, if the concentration of chrome in catfish meat accumulates in the body beyond the safe limit, then the long-term effects that will be caused in the form of a toxic response to the body. The effects caused as a result of the hoarding and continuous exposure of chrome metal in the body include kidney failure, cancer, skin irritation to death. In the short term, exposure and accumulation of chromium to humans can cause nausea and vomiting (Rahardjo &; Prasetyaningsih, 2017). It is possible for various skin, kidney, nerve diseases to develop cancer including lung, testicles and kidneys as a result of excess chromium buildup in human organs (Balali-Mood, Naseri, Tahergorabi, Khazdair, & Sadeghi, 2021).

Table 1

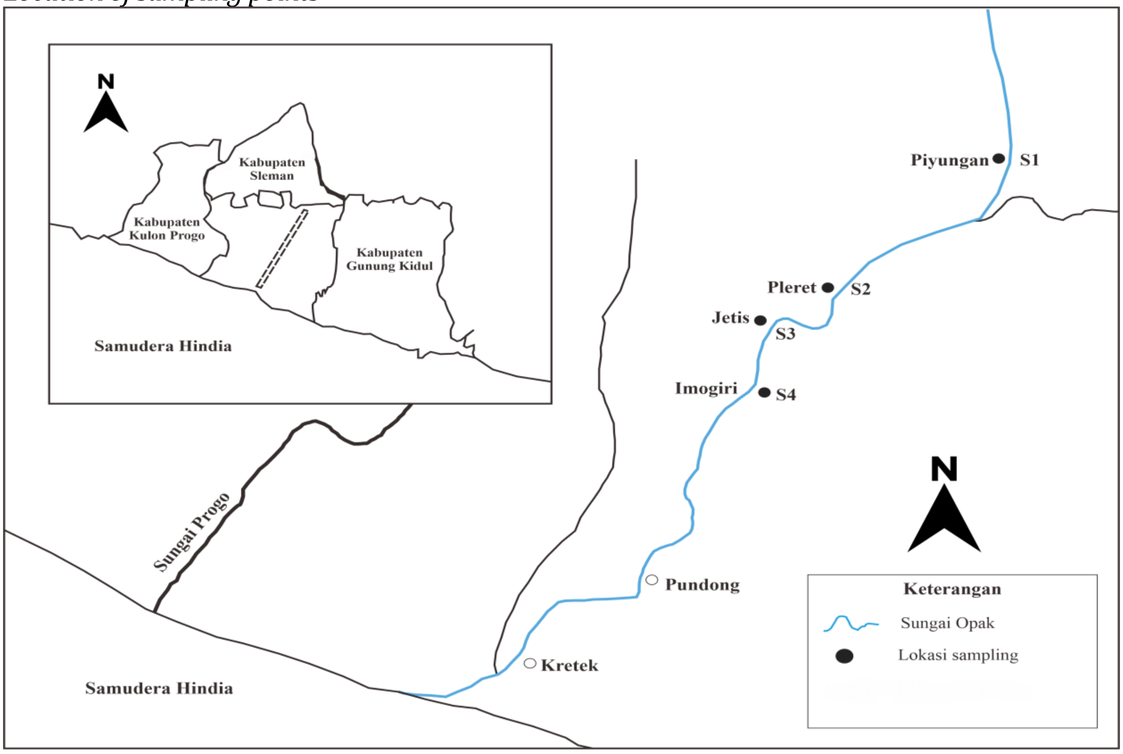
Concentration of heavy metal chrome (Cr) in water, sediment and catfish

No	Chrome Concentration	Unit	Sampling station				symbol
			Piyungan	Pleret	Jetis	Imogiri	
1	Water	mg/L	0,113	0,133	0,136	0,144	+
2	Sediment	mg/L	1,281	0,667	1,023	0,856	+
3	Catfish	mg/L	0,434	0,258	0,282	0,367	+

Table 2
The value of BCF in catfish meat

Sampling station	Organ	Cr concentration in organs (mg/L)	Cr concentration in water (mg/L)	BCF	Accumulation criteria
Piyungan	Meat	0,434	0,113	3,84	Low
Pleret	Meat	0,258	0,133	1,93	Low
Jetis	Meat	0,282	0,136	2,07	Low
Imogiri	Meat	0,367	0,144	2,54	Low

Figure 1.
Location of sampling points



Conclusion

The results showed that the BCF (bioconcentration factor) value of chromium heavy metal found in catfish was highest at Piyungan station with a value of 3.84 mg/L and the lowest at the station 1.93 mg/L. Based on the results of the classification of BCF Cr values against all samples included in the low accumulative category. The concentration value of chromium metal in catfish meat is still suitable for consumption so that the limit of chrome heavy metals in fish that can be tolerated by the human body per week is 1,398 mg / kg.

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