Analysis of heavy metal content and microbiological quality of fish and giant prawns chatch in Percut Watershed, Percut Sei Tuan District, Province of North Sumatra

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ARTICLE INFO

ABSTRACT

The purpose of this research was to determine the content of heavy metals and microbiological quality, and compare to the requirements of the quality standard values according to SNI 2729:2013 and SNI 2705:2014, as well as to determine the value of the Bioaccumulation Factor (BAF) and the maximum consumption limit of fish and giant prawns heavy metal-concentrated. This researh used survey and random sampling methods, i.e taking research samples (tilapia, broom fish, and giant prawns) at 3 (three) observation stations, including Station 1 Amplas, Station 2 Denai, and Station 3 Percut. Heavy metal content (Pb and Cd) and microbiological quality (*E. coli* and *Salmonella, sp*) were analysed. Data analysis was done by inference and calculated using Microsoft office Excel (Microsoft Inc., USA) descriptively. The results showed that all samples in each observation did not meet the quality standard value requirements according to SNI 2729:2013 and SNI 2705:2014. The average heavy metal content of Lead (Pb) was > 0,3 mg/kg in tilapia and broom fish, and > 0,5 mg/kg in giant prawns. The content of heavy metal Cadmium (Cd), were > 0,1 mg/kg in tilapia and broom fish, and > 0,5 mg/kg in giant prawns. All samples also showed positive in containing *E. coli* and *Salmonella, sp*. The value of Bioaccumulation Factor (BAF) of heavy metals (Pb and Cd) in all samples was > 1, meaning that the sample's ability to accumulate heavy metals (Pb and Cd) was high. The maximum limit for consumption of concentrated samples of heavy metals in tilapia was < 0,196 kg/week, broom fish was < 0,221 kg/week, and giant prawns was < 0,203 kg/week.

Introduction

Based on the watershed administration, Percut is located in 3 (three) regencies/cities, namely Deli Serdang Regency covering an area of 29.059,33 Ha (70,44 %), Karo Regency covering an area of 2.898,94 Ha (7,03%) and Medan City covering an area of 9.293,93 Ha (22,53%). The boundaries of the Percut watershed are in the north in the Melaka Strait watershed, in the south in the Ular and Wampu watersheds, in the west in the Deli watershed, and in the east in the Batang Kuis and Bedaai watersheds (Central Statistics Agency (BPS) of Deli Serdang Regency, 2019).

Community activities, industrial activities, and fuel pollution from motor vehicles around the flow of the Percut River cause various industrial waste to enter the river. The sources of these pollutants can cause heavy metal contamination from Cadmium (Cd), Lead (Pb) to pathogenic bacteria to the flow of the Percut River

(Safitri, 2014). Water contamination will lead to heavy metal poisoning in water biota which can be tested by AAS (Herto and alfian, 2015), this test can be used for aquatic biota such as tilapia (Jagfar, *et al.,* 2014).

Fish is one of the most widely consumed food sources of animal protein, since the price is affordable and relatively easy to obtain by the public. Types of farmed fish in Indonesia include freshwater, saltwater (sea), and brackish or lagoon fisheries (Mareta and Awami, 2011). Brooms grow relatively quickly without the need for intensive maintenance (Pinem, *et al.,* 2016). Fish is dangerous for consumption by the public, if the fish contains heavy metal levels that exceed the limits specified in SNI 2729:2013 regarding the requirements and parameters for the quality and safety of fresh fish, with a lead (Pb) value of 0,3 mg/kg and Cadmium (Cd) 0,1 mk/kg. The content of heavy metals in the fish body is closely related to the disposal of industrial waste

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around the fish's habitat, such as rivers, lakes, and the sea (Supriyanto *et al.*, 2007).

Pathogenic bacteria are common causes of *foodborne diseases* such as *Escherichia coli*, *Salmonella sp*, *Clampylobacter spp* and *Staphylococus aereus*. These bacteria will contaminate fish and shrimp which if consumed can be harmful to the health of consumers (Karimela, *et al.*, 2017). The research by Pangestu, *et al.* (2019) on the study of the microbiological quality of cage-cultured baung in the Kampar river, collecting samples at 3 stations, namely Air Tiris station, Teratak Buluh station and Buluh Cina station. The results of the observations showed that coliform bacteria were present in the baung fish in all three seasons, ranging from 6.87 APM/g to 8.87 APM/g. This value is above the minimum standard for coliform bacteria in fresh fish according to SNI 2725-1-2009, which is > 3 APM/g.

The other research by Lubis (2016) on the water quality of the Percut river based on the value of heavy metal levels of Pb by taking 3 stations as samples, namely station I in Medan Amplas District, station II in Medan Tembung District, and station III in Percut Sei Tuan district. The measurement results showed that at station I there was lead (Pb) of 0.08 mg/L, station II 0.04 mg/L, station III 0.06 mg/L. These results indicate that the lead (Pb) content in the water has exceeded the predetermined threshold value of 0.03 mg/L.

The phenomenon of pollution that occurs along the river has made researchers interested in analyzing the content of heavy metals in fish found in the Percut river estuary, Percut Sei Tuan District. The results obtained by the author will be adjusted to SNI 2729:2013 and SNI 2705:2014. Tilapia (*Oreochromis niloticus)*, Broomstick fish (*Pterygoplichthys* pardalis), and giant prawns (*Macrobrachium rosenbergii*) were selected for research due to the high production and consumption of fish and shrimp in the surrounding community.

Materials and Methods
Location and time of research

This research was carried out in August-September 2021 in the Percut watershed, North Sumatra, which was divided into three stations, namely Station 1 Amplas, Station 2 Denai, and Station 3 Percut. Analysis of heavy metals (Pb and Cd) was carried out at the Integrated Laboratory of the University of North Sumatra and the microbiological quality (*E. coli* and *Salmonella* sp.) was carried out at the Laboratory of Plant Diseases, Faculty of Agriculture, University of North Sumatra.

The method used in this research is survey method and *purposive random sampling*. The determination of the sampling site for sampling is selected based on the sources and activities of contaminants in the vicinity of the site.

a. Station 1

The research site is located in Timbang Deli Subdistrict, Medan Amplas Subdistrict, Medan Municipality, the sources of which are rubber factories, car and motorcycle exhaust and household waste.

Geographically, this station is located at $03^032'2.42''$ north latitude and $098^042'8.41''$ east longitude.

b. Station 2

The research site is located in Menteng Raya Village, Medan Denai District, Medan Municipality, whose pollution sources are household waste, agricultural sewage, gas station waste, convection waste from shoes and scrap metal storage. The distance between station 2 and station 1 is approximately 5.6 km. Geographically, this station is located at $03^034'0.93''$ north latitude and $098^043'2.69''$ east longitude.

c. Station 3

The research site is located in Muara Percut, Percut Sei Tuan District, Deli Serdang District and is a degraded area. The distance between station 3 and station 1 is approximately 24 km. Geographically, this station is located at $03^042'9.79''$ north latitude and $098^047'0.49''$ east longitude.

The sketch of the sampling location points can be seen in Figure 1.

Description:
→ = River flow direction
◯ = Sampling location
and ⬇ = Enter domestic waste
↔ = Distance between sampling locations
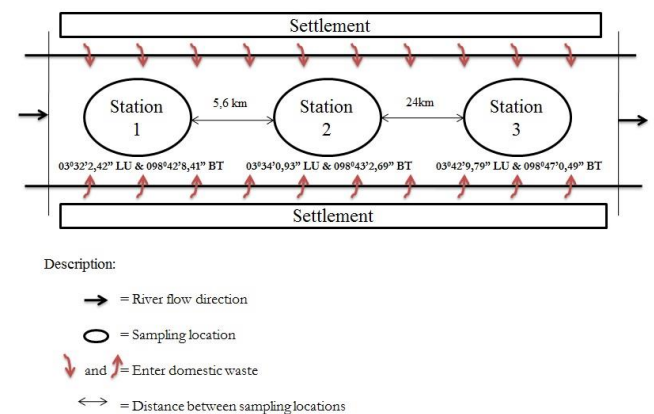
Measurement of Heavy Metals and Microbiological Quality

Measurement of heavy metals is carried out based on SNI 2354.5 (2011) regarding the determination of heavy metal levels of Lead (Pb) and Cadmium (Cd) in fishery products. Microbiological quality *E. coli* was carried out according to the established procedure based on SNI 01-2332.1-2006, while *Salmonella, sp.* carried out based on SNI 2725-1-2009.

Data analysis

The content of heavy metals (Pb and Cd) in the body tissues of giant prawns was compared with the quality requirements of fresh fish according to SNI 2729:2013 and SNI 2705:2014 regarding the quality requirements of frozen shrimp. with water quality requirements according to Government Regulation (PP) of the Republic of Indonesia (RI) No. 82 of 2001, concerning Water Quality Management and Water Pollution Control.

Analysis of microbiological data (*E. coli* and *Salmonella, sp.*) processed using *Microsoft office Excel* (Microsoft Inc., USA) descriptively and displayed in tabular form so that it can be seen the presence of

pathogenic bacteria in fish and giant prawns in the Percut river flow, North Sumatra Province.

The results of the concentration of heavy metals (Pb and Cd) in fish and giant prawns were calculated and the *Bioaccumulation Factor* (BAF) number and the maximum consumption limit for giant prawns and fish were calculated.

a. Real content

To get the actual concentration of heavy metals in fish, giant prawns, and water according to standard operating procedures at the USU Integrated Laboratory, the calculation of heavy metal content (Pb and Cd) in fish and giant prawns, the formula according to SNI 2354.5:2011 and river water is used. the formula according to SNI 6989.8:2009, as follows:

Pb and Cd fish and giant prawns (mg/kg) =

$$\frac{\text{K.AAS (mg/l) X Sample Solution (l) x FP}}{\text{Sample Weight (kg)}}$$

Heavy metal content (Pb and Cd) river water (mg/l) =
$$\text{K.AAS (mg/l) x FP}$$

Description: K.AAS= Concentration indicated on the AAS tool; Sample Solution = Volume of sample solution on when testing; Sample Weight = Weight of sample to be tested; FP = Diluent factor.

b. Determination *Bioaccumulation Factor* (BAF) in fish and giant prawns

The way to find out the mechanism of accumulation of heavy metals in aquatic organisms is to determine the value of the *Bioaccumulation Factor* (BAF) (Emilia, 2016). The bioconcentration factor can be calculated using the following formula (EPA, 2000):

$$BAF = \frac{Ct}{Cs}$$

Description: Ct = Heavy Metal Concentration in Organisms (mg/kg or ppm); Cs = Heavy Metal Concentration in Water (ppm).

Based on the BAF value category, pollutant properties are divided into 2 sequences, namely as follows:
BAF > 1 = High accumulation
BAF < 1 = Low accumulation

c. Determination of the maximum limit for heavy metal consumption in giant fish and prawns

According to Mirawati, *et al.* (2016), to find out the maximum value for heavy metal consumption or MTI (*Maximum Tolerable Intake* must first be found *Maximum Weekly Intake* using the formula (WHO, 2004) as follows:

$$\text{MWI = Body Weight x PTWI}$$

Description:

MWI = *Maximum Weekly Intake* is the maximum limit of heavy metal content from food per week (mg/week); Body Weight = Average body weight of Indonesian adults 60 kg body weight; PTWI = *Provisional Tolarable Weekly Intake* or the maximum tolerance limit per week which is expressed in mg/kg body weight/week.

After knowing the MWI value and knowing the levels of heavy metals in the test organisms, the maximum weight for consuming giant prawns and fish can be calculated every week. The value of *Maximum Tolerable Intake* (MTI) is calculated by the formula (WHO, 2004) as follows:

$$MTI = \frac{MWI}{Ct}$$

Description: MTI = *Maximum Tolarable Intake* or the maximum limit for consumption of fish and giant prawns (average weight of adults (60 kg body weight); Ct = Heavy metal content in the organism's body (mg/kg).

Results
River water

Based on the research that has been carried out, the results of heavy metal contamination (Pb and Cd) and microbiology (*E. coli* and *Salmonella, sp.*) in river water in the Percut river flow, Percut Sei Tuan District, North Sumatra Province can be seen in Table 1.

Fish and giant prawns

Based on the research that has been carried out, the actual concentrations of lead heavy metals (Pb and Cd) in tilapia (*Oreochromis niloticus)*, Broomfish (*Pterygoplichthys pardalis*), giant prawns (*Macrobrachium rosenbergii*) can be seen in Table 2.

Tabel 1. Contamination of heavy metals (Pb and Cd) and microbiology (*E. coli* and *Salmonella, sp.*) in river water.

Sample	Parameter	Results at Each Catching Location		
		Station 1 Amplas	Station 2 Denai	Station 3 Percut
River water*	Heavy metal contamination			
	a. Lead content (Pb) (mg/l)	1.186	1.208	0.693
	b. Cadmium content (Cd) (mg/l)	0.04	0.034	0.033
	Microbiological contamination			
	a *E.coli* (APM/g)	> 11000	> 11000	> 11000
	b. *Salmonella, sp.* (per 25 g)	Positive	Positive	Positive

Description: * The quality standard of heavy metal contamination (mg/l) and microbiology in river water is based on Government Regulation of the Republic of Indonesia RI No. 22 of 2021. Lead (Pb) maximum 0.03 mg/l, Cadmium (Cd) maximum 0.01 mg/l, *E.coli* < 1000 APM/g, *Salmonella, sp.* Negative per 25 g

Tabel 2. Contamination of heavy metals (Pb and Cd) and microbiology (*E. coli* and *Salmonella, sp.*) in fish and giant prawns.

Sample	Parameter	Results at each fishing location		
		Station 1 Amplas	Station 2 Denai	Station 3 Percut
Tilapia	Heavy metal contamination (Pb dan Cd)*			
	a. Lead content (Pb) (mg/kg)	7.640	6.607	7.070
	b. BAF	6.440	5.469	10.207
	c. MTI (kg/week)	0.196	0.227	0.212
	d. Cadmium content (Cd) (mg/kg)	0.290	0.360	0.380
	e. BAF	7.250	10.588	0.380
	f. MTI (kg/week)	1.448	1.167	1.105
	Microbiological contamination**			
	a. *E. coli* (APM/g)	> 11000	> 11000	> 11000
	b. *Salmonella, sp.* (per 25 g)	Positive	Positive	Positive
Broom fish	Heavy metal contamination (Pb dan Cd)*			
	a. Lead content (Pb) (mg/kg)	6.683	6.780	6.080
	b. BAF	5.634	5.613	8.778
	c. MTI (kg/week)	0.224	0.221	0.247
	d. Cadmium content (Cd) (mg/kg)	0.340	0.380	0.400
	e. BAF	8.500	11.176	12.121
	f. MTI (kg/week)	1.235	1.105	1.050
	Microbiological contamination**			
	a. *E. coli* (APM/g)	> 11000	> 11000	> 11000
	b. *Salmonella, sp.* (per 25 g)	Positive	Positive	Positive
Giant Prawns	Heavy metal contamination (Pb dan Cd)*			
	a. Lead content (Pb) (mg/kg)	6.880	7.407	7.040
	b. BAF	5.799	6.131	10.164
	c. MTI (kg/week)	0.218	0.203	0.213
	d. Cadmium content (Cd) (mg/kg)	0.360	0.450	0.470
	e. BAF	13.235	13.235	14.242
	f. MTI (kg/week)	0.933	0.450	0.894
	Microbiological contamination**			
	a. *E. coli* (APM/g)	> 11000	> 11000	> 11000
	b. *Salmonella, sp.* (per 25 g)	Positive	Positive	Positive

Description: *the quality standar of heavy metal of Lead (Pb) maximum was 0.3 mg/kg, Cadmium (Cd) maximum was 0.1 mg/kg (SNI 2729:2013, SNI 2705:2014), BAF (*Bioaccumulation Factor*), MTI *(Maximum Tolerable Intake)*. ** Standard of *E. coli* < 3 APM/g, *Salmonella, sp.* Negative per 25 g (SNI 2729:2013, SNI 2705:2014)

Discussion

Analysis of heavy metal contamination (Pb and Cd) of river water in the Percut river, Percut Sei Tuan District, North Sumatra Province

Based on Table 1, it can be seen that the heavy metal content of Lead (Pb) and Cadmium (Cd) of river water varies. The location of the sampling can affect the heavy metal content in river water. Station 1 river water samples were taken before the paper mill waste disposal site. Station 2 river water samples were taken before the location of the Denai Water Treatment Plant (IPA) with a distance of about 7 km. Station 3 river water samples were taken after the Percut chart tourist location, including the Fish Auction Place (TPI), *restaurants*, and tourist boat taxis. Based on the location of the water sampling, it was found that the heavy metal content of station 2 river water was higher than

other stations, because the waste discharged by the paper mill into the river caused the Denai river to be increasingly polluted. Therefore, the Governor of Sumatra, Edy Rahmayadi, inaugurated the Denai WTP, which is expected able to increase the supply of clean water to meet the needs of the people of Medan City, especially in the Medan Denai District, Medan Tembung, and surrounding areas (PDAM Tirtanadi, 2020).

The results obtained can be stated that the content of heavy metals (Pb and Cd) in river water in the Percut river has exceeded the quality standard value set by Government Regulation of the Republic of Indonesia No. 82 of 2001. From this it can be said that the content of heavy metals (Pb and Cd) in polluted river water can endanger the life of biota and the surrounding environment. Based on data from the Central Statistics Agency (BPS) of the

Ministry of the Environment (2020), regarding the status of river water quality, the Percut river obtained a moderate-to-heavy polluted status from 2007-2016. According to the report book on the Regional Environmental Status of North Sumatra Province (2015), that the status of river water quality in Medan Amplas is classified as heavily polluted.

Based on the results of the Siregar research (2019), the results of the questionnaire show that as many as 62% of research subjects drain household liquid waste directly without processing into the river, as many as 41% of respondents still throw their daily waste into the river, as many as 13% of respondents still wash in the river. rivers, as many as 13% of respondents carried out bathing, defecating and urinating in rivers, as many as 16% of respondents throwing pesticides into rivers, as many as 30% of respondents throwing dead animals into rivers, as many as 18% of respondents throwing animal waste into rivers, and as many as 36% of respondents drain their fecal waste directly into the river. It is also known that as many as 11% of respondents still use Percut River water as a source of clean water.

Analysis of microbiological contamination (*E. coli* and *Salmonella, sp.*) of river water, Percut Sei Tuan District, North Sumatra Province

Based on Table 1, it can be seen that three stations of river water from the Percut river flow showed positive results for *E. coli contamination*. It is recommended for the community around the Percut river water flow not to use the water for daily needs, such as using the water for bathing and washing clothes which will cause diseases such as diarrhea.

Usually, *Salmonella* and *E. coli* bacteria come from animals and humans. If this type of bacteria is found in the waters, it indicates that there is pollution in the waters, so these bacteria can be used as an indicator of pollution. As found by Papadopoulou, *et al.* (2007) that *Salmonella* and *E. coli* are indicator organisms of *fecal* that do not come from the aquatic environment. According to Papadopoulou, *et al.* (2007), *Salmonella* and *E. coli* are indicator microorganisms of non- *endigenous pollution* in the aquatic environment. In addition, contamination *E. coli* and *Salmonella* in shrimp occurs due to poor sanitation and hygiene conditions.

Analysis of heavy metal contamination (Pb and Cd) of fish and giant prawns in the Percut river, Percut Sei Tuan District, North Sumatra Province

Based on Table 2, it can be seen that the levels of heavy metals (Pb and Cd) in fish and giant prawns caught in the Percut river have varying concentrations at each station and exceed the quality standard values set by SNI 2729:2013 and SNI 2705:2014. The high content of heavy metals in the meat of giant prawns and fish is thought to be due to the accumulation of heavy metals due to high heavy metal contamination in the water. According to Jagfar, *et al.* (2014), heavy metal content in water affects the life of aquatic organisms because of the ability of aquatic organisms to accumulate heavy metals in water. Tilapia, broomstick fish, and giant prawns are omnivorous (Hadie and Hadie. 2001; Prihardhyanto, 1995) so that the potential for accumulation of heavy metals in the body is greater than that of herbivorous and other carnivorous fish.

The calculation results showed that tilapia had a higher lead content of heavy metal (Pb) compared to broomstick fish and giant prawns even though the three samples were omnivorous. This is because tilapia has a wide tolerance for environmental quality, has good growth ability and has water quality and disease resistance (Oktapiandi, *et al.*, 2019).

Bioaccumulation factor (BAF) or bioaccumulation factor is the accumulation of metals by fish taken directly from the water. According to EPA (2000), BAF is a process of accumulation of chemicals such as heavy metals in an organism through various routes such as respiration, food consumption or direct contact with polluted water (EPA, 2000).

Based on Table 2, it can be seen that the BAF value of heavy metals Lead (Pb) and Cadmium (Cd) in fish and prawns percut river flow is more than 1. These results indicate that the accumulation of heavy metals Lead (Pb) is classified as high bioaccumulation. This can endanger the survival of fish and giant prawns. According to Rumahlatu (2011), an increase in heavy metal levels in river water will be followed by an increase in heavy metals in fish and other biota, so that contamination of river water by heavy metals will result in polluted fish living in it.

Accumulation of heavy metals (Pb and Cd) is classified as high bioaccumulation. According to Franchini, *et al.* (2015), this value can indicate the ability of organisms to accumulate heavy metals. The accumulation ability is said to be high if the BAF value is > 1. Meanwhile, if the BAF value is < 1, the heavy metal accumulation ability is low. Therefore, it can be seen that giant fish and prawns have good accumulation capabilities of lead (Pb) and cadmium (Cd). The level of accumulation of

toxic substances is influenced by the fish's body's efforts in detoxification and excretion processes (Yulaipi and Aunurohim, 2013).

Maximum Tolerable Intake (MTI) is the maximum weight in consuming food contaminated by heavy metals every week. The maximum consumption value is used to reduce the negative effects of heavy metals that enter the human body.

Based on the calculation results, it was found that the maximum consumption of tilapia with heavy metals (Pb and Cd) was a maximum of 0.196 kg/week, broom fish concentrated heavy metals (Pb and Cd) was a maximum of 0.221 kg/week, and giant prawns concentrated heavy metals (Pb and Cd). Pb and Cd) maximum 0.203 kg/week. The MTI value taken is the smallest value. According to Hidayah, *et al.* (2014), the maximum limit for consumption of fish meat is determined by choosing the smallest value, because fish meat contaminated with heavy metals even in small concentrations but if consumed continuously will accumulate in the human body and will be toxic.

Analysis of microbiological contamination (*E. coli* and *Salmonella, sp.*) of fish and giant prawns in the Percut River, Percut Sei Tuan District, North Sumatra Province

The test results showed that all test samples were positive with the presence of colonies with *E. coli*. The *Most Probable Number* (MPN) value of giant prawns and fish shows that the *E. coli* exceeds the quality standard limits. The MPN value in accordance with the determined Indonesian National Standard (SNI) is less than 3 APM/g. The Percut river flow is a river flow that goes to the open seas, so the samples obtained should be better. However, the APM value showed that the fish and giant prawns were contaminated with *E. coli*.

This can be caused by unhygienic environmental conditions with the habit of residents throwing organic waste, human waste on the edge of the waters so that contamination is carried away by the tides plus poor handling. According to Machairiyah *et al.* (2020), organic waste is the dominant waste polluting the Percut river. Organic waste pollution that occurs in the Percut River is caused by anthropogenic activities such as the use of agricultural land and settlements. Therefore, the results of the calculation of *E. coli* exceed the standard threshold set by SNI and indicate giant fish and prawns originating from the Percut river are not suitable for consumption.

Test results *Salmonella, sp.* showed that all samples of fish and prawns caught in the Percut watershed were positive in the isolation test for *Salmonella, sp.*

The contamination of giant prawns and fish is caused by the distance between the river and adjacent residential areas, while there are still some people who lack awareness of environmental hygiene so that they dispose of their feces carelessly and some even throw their feces on the banks of the river itself, this has the potential to trigger the growth of pathogenic bacteria *Salmonella, sp.*. This is in accordance with WHO (2004), which says that pollution can also occur from sources from rivers or other sources where fish and shrimp breed. Pollution can come from contamination of liquids or solids that enter river water, and this water can be a means of spreading *Salmonella, sp.*

Conclusion

The results showed that all samples in each observation did not meet the requirements of the quality standard values according to SNI 2729:2013 and SNI 2705:2014. The average heavy metal content of Lead (Pb) was > 0.3 mg/kg in tilapia and broom fish, and > 0.5 mg/kg in giant prawns. The content of heavy metal Cadmium (Cd), namely > 0.1 mg/kg in tilapia and broomstick, and > 0.5 mg/kg in giant prawns. All samples also showed positive to contain *E.coli* and *Salmonella, sp*. The value of *Bioaccumulation Fa ctor* (BAF) of heavy metals (Pb and Cd) in all samples is > 1, meaning that the sample's ability to accumulate heavy metals (Pb and Cd) is high. The maximum limit for consumption of concentrated samples of heavy metal Lead (Pb) is a maximum of 0.2 kg/week and Cadmium (Cd) is a maximum of 1.2 kg/week.

References

Central Statistics Agency (BPS) of Deli Serdang Regency. 2019. Deli Serdang dalam Angka 2019.

Central Statistics Agency (BPS) of the Ministry of the Environment. 2020. Status Kualitas Air Sungai. http:bps.go.id [Accessed November, 02, 2021].

Emilia, I. 2016. Biokonsentrasi logam Kadmium (Cd) dalam jaringan remis (*Corbicula sp.*) terhadap lingkungan abiotik (air dan sedimen) di perairan sungai musi kota Palembang. Sainmatika:Jurnal Ilmiah Matematika dan Ilmu Pengetahuan Alam. 12 (1) : 25 – 31.

EPA. 2000. Bioaccumulation testing and interpretation for the pupose of sediment quality assessment status and needs. United State Enviromental Protection Agency.

FAO. 2019. The state of and nutrition food security in the world: safeguarding against economic slowdowns and downturns. In IEEE Journal of Selected Topics in Applied Earth Observation and Remote Sensing. 7(7).

Franchini, I.R., M.L. Hernandez, M.G.R. Espinosa, R.R. Martinez. 2015. Bioaccumulation of metals arsenic, cadmium, and lead in zooplankton and fishes from the Tula River Watershed, Mexico. Water, Air, & Soil Pollution. 227(5): 1–12.

Hadie, W., L.E. Hadie. 2001. Tingkah laku makan dan molting pada udang. Prosiding Penelitian Budi daya Udang Galah. Pusat Riset Perikanan Budidaya.

Herto, A., M. Alfian. 2015. Analisis kandungan logam berat Timbal (Pb) dan Zn di perairan tambak Kabupaten Gresik. Jurnal Perikanan. 1(1):26–34.

Hidayah, A. M., Purwanto, T.R. Soeprobowati. 2014. Biokonsentrasi faktor logam berat Pb, Cd, Cr dan Cu pada ikan nila (*Oreochromis niloticus Linn.*) di karamba Danau Rawa Pening. Bioma. 16(1): 1–9.

Jagfar, Agustono, A. Mizar. 2014. Deteksi logam berat Timbal (Pb) pada ikan nila di sepanjang sungai Kali Mas. Jurnal Ilmiah Perikanan dan Kelautan. 6(1): 42–48.

Jenie, B.S.L. 2007. sanitasi dalam penanganan pangan: sumber kontaminasi dan mikroba indikator. Modul 1. PAU Pangan dan Gizi, IPB-Press, Bogor.

Karimela, E.J., I.G. Frans, H.A. Dien. 2017. Karakteristik *Staphylococcus aureus* yang diisolasi dari ikan asap pinekuhe hasil olahan tradisional Kabupaten Sangihe. Jurnal PHPI. 20(1):188–198.

Lubis, E.S. 2016. Analisis kandungan logam berat Timbal (Pb) pada ikan mujair (*Oreochromis Mossambicus)* di daerah aliran Sungai Percut Kecamatan Percut Sei Tuan Provinsi Sumatera Utara Tahun 2015. Skripsi Fakultas Kesehatan Masyarakat. USU-Press, Medan.

Machairiyah, Z. Nasution, B. Slamet. 2020. Pengaruh pemanfaatan lahan terhadap kualitas air Sungai Percut dengan metode Indeks Pencemaran (IP), Jurnal LIPI. LIMNOTEK Perairan Darat Tropis di Indonesia. 27(1): 13–25.

Mareta, D.T. S. Awami. N. 2011. Pengawetan ikan bawal dengan pengasapan dan pemanggangan. Jurnal Ilmu–ilmu Pertanian. 7(2):33–47.

Oktapiandi, J. Sutrisno, Sunarto. 2019. Analisis pertumbuhan ikan nila yang dibudidayakan pada air Musta'mal. Bioeksperimen. 5(1): 16–20.

Pangestu, R., B. Hasan, N.I. Sari. 2019. Studi mutu mikrobiologi ikan baung (*Hemibagrus nemurus*) budidaya keramba di Sungai Kampar, Riau. Jurnal Fakultas Perikanan dan Kelautan UNRI. Pekanbaru.

Papadopoulou, C., E.G. Economou, C. Zakas, C. Salamoura, C. Dontorou, J. Apostolou. 2007. Microbiological and pathogenic contaminants of seafood in Greece. Journal of Food Quality. 30: 28-42.

Pinem, F.M. Pulungan, C.P., D. Efizon. 2016. Reproductive biology of *Pterygoplicthys Pardalis* in the Air Hitam River Payung Sekaki District. Riau Province. Jurnal Pnline Mahasiswa. 3(1): 1–4.

Prihardhyanto, A. 1995. Beberapa aspek biologi ikan sapu-sapu (*Hypostomus sp* dan *Lyposarcus pardalis*). Jurnal FMIPA UI. Depok. 5: 15–60.

PDAM Tirtanadi. 2020. PDAM Tirtanadi wujudkan komitmen dengan pembangunan IPA Denai. http://pdamtirtanadi.co.id [Accessed December, 08, 2021].

Regional Environmental Status of North Sumatra Province. 2015. Kondisi Lingkungan dan Kecenderungan. Pemerintah Provinsi Sumatera Utara.

Rumahlatu, D. 2011. Konsentrasi logam berat Kadmium pada air, sedimen dan *Deadema setosum* (*Echinodermata, Echinoidea*) di perairan Pulau Ambon. Ilmu Kelautan. 16(2): 78–85.

Peraturan Pemerintah Republik Indonesia Nomor 22 tahun 2021. Penyelenggaraan perlindungan dan pengelolaan lingkungan hidup.

Safitri, R. 2014. Kandungan logam Kadmium (Cd), Timbal (Pb) dan Merkuri (Hg) pada air dan komunitas ikan di Daerah Aliran Sungai Percut. Tesis. Universitas Sumatera Utara. Medan.

Siregar, A. M. S. 2019. Perhitungan beban pencemaran dari parameter Total Suspended Solid (TSS) dan total *Coliform* serta pengaruh perilaku masyarakat terhadapo kualitas air Sungai Percut. Skripsi USU, Medan.

Standar Nasional Indonesia 01-2332.1-2006. Bagian 1: penentuan *Coliform* dan *Escherichia coli* pada produk perikanan.

Standar Nasional Indonesia 06-6989.16-2004. Air dan limbah – Bagian 16: cara uji Kadmium (Cd) dengan Metode Spektrofotometri Serapan Atom (SSA).

Standar Nasional Indonesia 2354.5:2011. Cara uji kimia – bagian 5: penentuan kadar logam berat Timbal (Pb) dan Kadmium (Cd) pada produk perikanan.

Standar Nasional Indonesia 2725-1-2009. Bagian 2: penentuan *Salmonella* pada produk perikanan.

Standar Nasional Indonesia 2705:2014 mengenai persyaratan mutu udang beku.

Standar Nasional Indonesia 2729:2013. Persyaratan mutu ikan segar.

Standar Nasional Indonesia 6989.8:2009. Air dan limbah – bagian 8: cara uji Timbal (Pb) secara Spektrofotometri Serapan Atom (SSA).

Supriyanto, C., Samin, Z. Kamal. 2007. Analisis cemaran logam berat Pb, Cu, dan Cd pada ikan air tawar dengan metode spektrometri Nyala Serapan Atom (SSA). Proceedings of the Jurnal Seminar Nasional III SDM Teknologi Nuklir, Yogyakarta. 147–152.

WHO (World Health Organization). 2004. Summary of evaluations performed by the joint FAO/WHO expert commitee on food additives (JECFA 1956-2003). ILSI Press International Life Sciences Institute. Washington.

Yulaipi, S., Aunurohim. 2013. Bioakumulasi logam berat Timbal (Pb) dan hubungannya dengan laju pertumbuhan ikan mujair (*Oreochromis mossambicus*). Jurnal Sains dan Seni Pomits. 2(2): 166–170.