Heavy metal content (Cd and Cu) in the flesh and gills of ponyfish (*Leiognathus Equulus*) in Cilincing coastal waters, Jakarta bay

Aliza Tinur Awwali, *Sulistiono*[*], *Sigid* Hariyadi, *Etty* Riani, and *Jessica* Sinaga

Department of Aquatic Resources Management, Faculty of Fisheries and Marine Science, IPB University, Dramaga Bogor, 16680, West Java-Indonesia

Abstract. Cilincing coastal waters, as one of the coastal waters of Jakarta Bay, apart from being a fishing ground for local fishermen, is also a location for various community activities, including residential, industrial, transportation, shipping and tourism. One of the fish resources in the region is ponyfish (*Leiognathus equulus*). These various community activities can produce waste which has an impact on the fish. This study aims to analyze the heavy metal content in the flesh and gills of ponyfish exposed to heavy metals caught in Cilincing coastal waters, Jakarta Bay. Sampling was carried out for 6 months (February - July 2023). Analysis of heavy metal content in flesh and gills was carried out using *Atomic Absorption Spectrophotometer*. The content of the heavy metal Cd in flesh and gills exceeds quality standards. In the fish samples, inflammatory cell infiltration was found (in the fish flesh) and there was edema, lamella fusion, basal cell hyperplasia and secondary cell hyperplasia (in the fish gills). Based on calculations, the safe limit for consumption of ponyfish caught in Cilincing waters should be no more than 1.858 kg of flesh/week for adults and 0.558 kg of flesh/week for children.

1 Introduction

The ocean has a crucial role in supporting life, both for plants and animals that choose it as their living environment. In addition, the ocean also plays a crucial role for humans as a source of livelihood for people to fulfill their needs. As the ocean plays a significant role in many sectors, it is important for all parties to consider measures to mitigate marine pollution. The ocean is often used as a dumping ground for garbage or waste from various human activities because it is considered an efficient and cheap way. The ocean is often a dumping

[*] Corresponding author: onosulistiono@gmail.com

ground for garbage or waste from various human activities because it is considered an efficient and cheap way. So that many types of garbage and pollutants are found, especially metals. According to [1], marine pollution is the entry or inclusion of contaminants into a body of water that can cause the water to not be in accordance with its designation. Human activities that are dominant on land, whether realized or not, can directly or indirectly affect marine ecosystems.

One area that has high activity that can cause marine pollution is the Cilincing Waters. Cilincing waters are located in the northern part of Jakarta Bay, which plays an important role in Indonesia's economic growth. According to [2] the Jakarta Bay area, which stretches along 32 km, is the center of major socio-economic activities, including Tanjung Priok Port which provides transportation services for passengers and containers, industrial activities, timber loading and unloading, fish landing, storage warehouses, and the tourism sector. Abundant human activities around Cilincing Waters have the potential to affect the environment, especially the aquatic environment, through the waste produced, both directly and indirectly, which can cause damage to aquatic ecosystems and lead to heavy metal pollution in the waters.

Heavy metals are dangerous pollutants because they tend not to biodegrade and usually accumulate in water, bottom sediments, and the bodies of organisms. Increased development around the Jakarta Bay Waters, along with an ever-increasing population growth can potentially reduce the quality of these waters. The most common heavy metals found in effluents from industrial areas are Cadmium (Cd), and Copper (Cu). Based on the current condition of Cilincing Waters, fish caught by fishermen in the area are thought to be exposed to heavy metals. One of the fish that is often caught is ponyfish (*Leiognathus equulus*). According to [3] ponyfish is a type of demersal fish that has a habitat in coastal waters, bays, river mouths, and freshwater, usually living in large groups. Ponyfish distribution in Jakarta Bay Waters is quite abundant, even the number covers about half of the ponyfish population throughout Indonesia [4]. Heavy metal-related pollution of water, sediment and ponyfish has been conducted previously in Jakarta Bay by [5], [6], [7], [8], [9], and [10] in Banten Bay Waters. However, there is no report on heavy metal pollution in ponyfish caught in Cilincing. Therefore, it is important to conduct research related to the content of heavy metals Cd and Cu in the flesh and gills of ponyfish in Cilincing Waters, North Jakarta. Therefore, this research is very important to do. This study aims to analyze the content of heavy metals in the flesh and gills of ponyfish exposed to heavy metals caught in the coastal waters of Cilincing, Jakarta Bay.

2 Materials and methods

2.1 Time and location of research

This research was conducted from February to July 2023. The research site was located in the waters of the Cilincing Coastal Waters, Jakarta Bay (Figure 1).

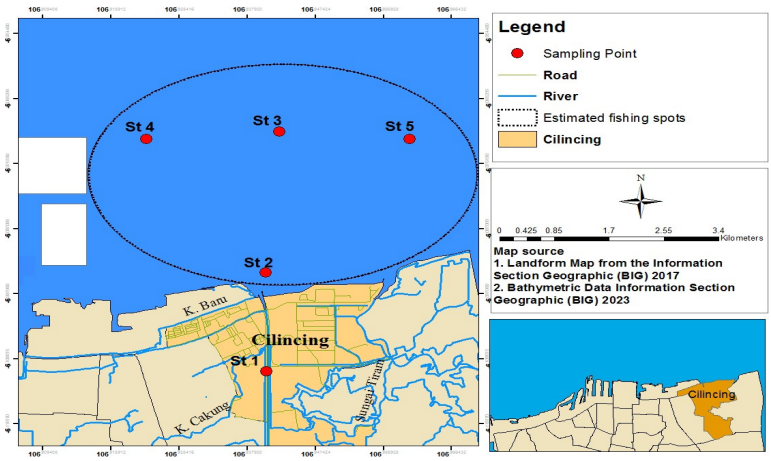

Fig. 1. Map of research location

The Ponyfish dissection process was carried out at the Macro Biology Laboratory I, Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences. Analysis of heavy metals in flesh and gills was carried out in the Integrated Laboratory, IPB Baranangsiang Campus, while analysis histomorphology in Aquatic Organism Health Laboratory, Aquaculture, FPIK IPB.

2.2 Data collection

2.2.1 Sampling of ponyfish

Ponyfish samples were taken using a non-probability sampling method due to the opportunity to take samples in an unequal population, which is around 25 - 35 fish in each month. Samples were taken using purposive sampling technique based on the presence of fish and the source of pollutants. Ponyfish samples were taken every February - July 2023 at stations 2 to 5 which are influenced by the Cilincing River.

Samples of ponyfish were captured using boats and fishing gear in the form of gill nets that have a mesh size of 2 inches. The size of the fish taken is about 13 cm - 22 cm with a weight of about 20 - 75 g from the total sample every month. Fish collection was carried out in the morning before water sampling, sample fish obtained were then put into labeled plastic and put into a coolbox filled with ice to maintain fish freshness.

2.2.2 Harvesting ponyfish flesh and gills

Fish samples were measured in length using a ruler and weighed using digital scales. Then the ponyfish samples were dissected and the flesh and gills were taken as much as 50 to 100 g (according to the direction of the laboratory where the samples were tested) from the total fish samples caught every month to be analyzed for heavy metals, to determine the concentration of heavy metals Cd and Cu in the flesh and gills of ponyfish using *Atomic Absorption Spectrophotometer* (AAS). The AAS method can be used to test for heavy metals in all types of fish.

2.2.3 Observation of fish tissue histomorphology

The samples used for histomorphological analysis were the flesh and gills of ponyfish. Before being analyzed using the histomorphology method, the fish was first separated from the flesh and gills and then put into Davidson's solution as a preservative to inhibit the decay process in the flesh and gills of the fish. The samples used were fish suspected of heavy metal exposure. The samples used were fish suspected of being exposed to heavy metals.

2.3 Data Analysis

2.3.1 Bioconcentration factor (BCF)

The bioconcentration factor is the ratio between the concentration of chemicals in the body of aquatic organisms and the concentration of chemicals in water. This bioconcentration calculation is used to see how much heavy metal concentration is in the waters and in the body of the biota tested. Determine the BCF value using the formula :

$$BCF = \frac{Concentration\ of\ heavy\ metals\ in\ organism}{Concentration\ of\ heavy\ metals\ in\ water} \quad (1)$$

Where low accumulation is BCF < 100, medium accumulation is 100 < BCF ≤ 1000, and high accumulation is BCF > 1000

2.3.2 Maximum Tolerable Intake (MTI)

MTI is the maximum tolerance limit for consumption of fish exposed to heavy metals. The maximum weight limit of Ponyfish flesh that can be tolerated for consumption within one week Maximum Tolerable Intake (MTI) is calculated using the following formula :

$$MTI = \frac{MWI}{Ct} \quad (2)$$

Information :
MWI : *Maximum Weekly Intake* (mg for adults weighing an average of 50 kg and children weighing an average of 15 kg per week)
Ct : Concentration of heavy metals in the analyzed organism (mg/kg)

3 Results and discussion

3.1 Cd and Cu content in flesh and gills of ponyfish

Pollution has become a problem for most water areas in Indonesia, including pollution in Jakarta Bay. Pollution in Jakarta Bay is caused by the high level of community activity in the area. One of the areas that has high activity part of Jakarta Bay is Cilincing Waters. Cilincing Waters is located in the northern part of Jakarta Bay and is the estuary of the Cakung River. The high activity of the community around Cilincing Waters can cause a decrease in water quality, which is the dominant area in Cilincing Waters. One of the pollutants that has the potential to cause a decrease and damage to the environmental carrying capacity of Cilincing Waters is heavy metals. One of the fishermen's catches in Cilincing Waters that is suspected to be exposed to heavy metals is ponyfish. Ponyfish is a demersal fish that lives in clusters and has quite economic value. The consumption level of ponyfish in Cilincing is quite high, therefore it is necessary to analyze the heavy metal content in this fish.

The results of the analysis of Cd heavy metal content exceeded the quality standard in flesh and gills, while Cu in flesh and gills was below the specified quality standard. The quality standards for Cd and Cu heavy metal content in flesh and gills are adjusted to the

quality standards set by BPOM for processed food. The heavy metal content of Cd and Cu in Ponyfish is presented in Figure 2.

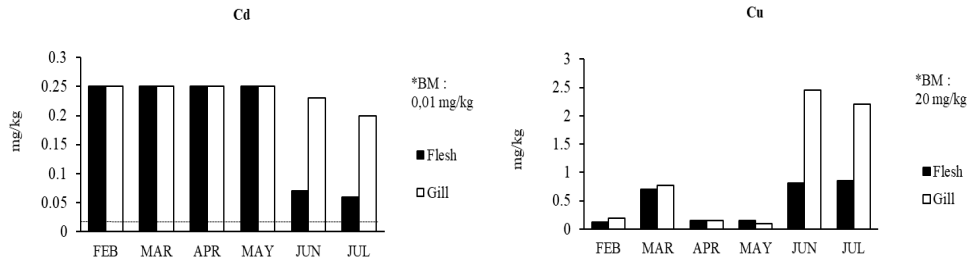

Fig. 2. Content of heavy metals (Cd and Cu) (mg/kg) in the flesh and gills of Ponyfish

The important part analyzed in fish to see the heavy metal content is the flesh because it is the most important part consumed by humans. Heavy metals can be stored in the body of an organism for a long period of time and are toxic. If humans consume food containing heavy metals continuously, it will endanger human health. The content of heavy metals in fish varies in each part, with higher concentrations of heavy metals found in gonads, bones and fish heads. Heavy metals enter the body of organisms through several ways, namely inhalation (through breathing), through the digestive tract and also through the skin. The highest Cd content in Ponyfish flesh and gills was found in February – July. The Cd content in flesh and gills has exceeded the quality standard set by BPOM which is 0.01 mg/kg. The value of heavy metal Cd in Cilincing Waters is thought to be caused by several factors, namely waste from port operations and waste input from Cakung River water which flows directly into Cilincing Waters. Studies on heavy metal Cd in demersal fish other than pepetek were also conducted on mullet and baronang fish in Benoa Bay, Bali [11]. In this study, the Cd heavy metal content was above the quality standard threshold, besides that research on the Cd heavy metal content of other demersal fish was also conducted around Jakarta Bay by [12] on pomfret, pepetek and mackerel. The Cd content of fish in the flesh of pomfret, ponyfish and mackerel caught in Jakarta Bay has varying values where pomfret and mackerel have Cd content above the specified threshold while petek fish is below the maximum set. Heavy metal Cd can accumulate in almost all fish tissues and organs, such as liver, kidney, and gills with high accumulation rates while in muscle tissue the level of Cd accumulation tends to be less.

The entry of heavy metal Cd into the body of fish can cause damage to fish organs. The presence of Cd in the body of ponyfish is due to the heavy metal Cd in the water does not cause avoidance of the ponyfish. Heavy metals that have entered the fish body cannot be removed naturally by the fish, then heavy metals are transported to all parts of the body through the bloodstream. According to [13], Cd heavy metals that have been transported throughout the body will accumulate in the muscles of fish with a long exposure time. Cd heavy metal is a non-essential metal and has been classified as a carcinogenic material. [14] said that about 90% of humans who do not smoke can be exposed to Cd from food, especially those who consume shellfish and flesh and marine animals.

Cu heavy metals naturally enter the aquatic environment through particulate dust from the air carried by rain or from the waters themselves. In general, heavy metal Cu comes from mining and industrial waste such as paint as anti-fouling. According to [15] heavy metal Cu is an essential metal needed by living things in certain amounts, and if it exceeds the tolerance limit it can endanger the life of these biota. Ponyfish caught in Cilincing Waters have Cu content in flesh and gills below the quality standard set by BPOM which is 20 mg / kg. The results of this study are in line with the research of [10] which states that the Cu content in

ponyfish caught in Banten Bay has a value that is below the quality standard threshold. According to [10], the low Cu content in fish flesh is due to the biological characteristics of fish which are organisms that live in the water, so that the heavy metal content in their habitat is low and the accumulation rate in the fish body is lower. The impact of heavy metal accumulation in fish can reduce the level of gonad maturity, close the gill membrane so that fish will lack oxygen and can inhibit the growth of a fish and the flesh of the fish becomes unsafe for consumption. Consuming unsafe food can cause a disease called foodborne disease, namely symptoms of disease that arise from consuming food containing toxic materials or pathogenic organisme.

3.2 Histomorphology of ponyfish

Histomorphology is the microscopic study of cells and tissues through staining and viewing under a microscope. Histological tissue processing serves in the diagnosis of diseases that involve changes in physiological functions and organ deformations. Heavy metals such as cadmium and copper are pollutants that can affect the aquatic environment and fish. According to [16] heavy metals can pose a serious risk to the aquatic environment due to their toxicity, accumulation and growth. Most of these heavy metals are classified as hazardous substances in many countries due to their toxicity, persistence and bioaccumulation properties. These heavy metals can effectively affect major metabolic processes, fish reproduction, weaken the immune system and cause pathological changes [17]

The histomorphology of ponyfish exposed to heavy metals showed that there was inflammatory cell infiltration in the flesh and basal cell hyperplasia, edema, secondary cell hyperplasia and secondary lamella fusion in the gills. The images of flesh and gills exposed to heavy metals are presented in Figures 3 and 4.

Fig. 3. Histomorphology of ponyfish flesh samples taken at the study location. Flesh cells have Inflammatory Infiltration (II).400x

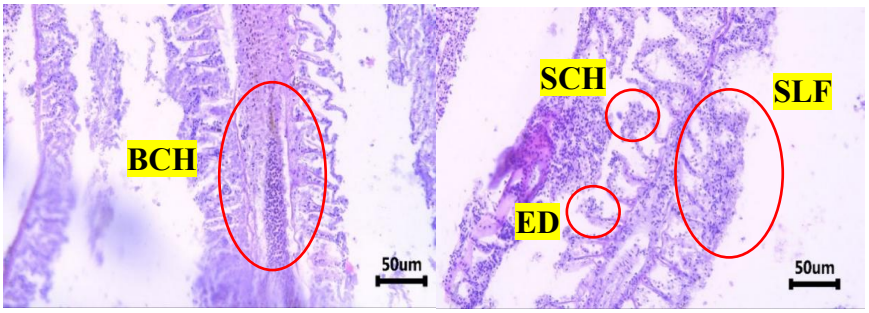

Fig. 4. Histomorphology of ponyfish gill samples taken at the study site. a). basal cell hyperplasia (BCH) 400x. b). Edema (ED), Secondary cell hyperplasia (SCH), and Secondary lamellar fusion (SLF) 400x.

In aquatic ecosystems, fish are key indicators of environmental pollution as they are at the top of the aquatic food chain and are known to accumulate toxins. Dissolved heavy metals in water bodies at certain concentrations will become a source of poison for organisms in the waters. In Cilincing, Ponyfish is a consumable fish that has an economical price and is easily obtained by fishermen. In addition, ponyfish also contains high protein and calcium which are beneficial for the body. Based on the results of the study, ponyfish caught in Cilincing Waters experienced inflammatory cell infiltration. Inflammatory cell infiltration is characterized by increased permeability of blood vessels, fluids, and cells that come out of blood vessels and the presence of netrophils in tissues that are inflamed. According to [18], histopathological changes that occur in fish flesh are changes involving excessive growth, imperfect growth, or abnormal growth patterns in muscle tissue and degeneration.

Apart from the flesh, the gills of Ponyfish caught in Cilincing waters are also damaged due to exposure to heavy metals. Some organs are directly affected by exposure to heavy metal Cd, such as the gills. The gills are the first organ to be attacked because the gills are an organ that interacts directly with water and where ions are absorbed. Damage to fish gill tissue includes basal cell hyperplasia, edema, hyperplasia, and secondary lamella fusion. The thin epithelial layer of the gills and direct contact with the external environment causes the gills to have a great opportunity to be exposed to pollutants in the waters. Minor damage to the gills can cause disruption of their function as osmosis regulators and respiratory difficulties. Fish exposed to heavy metals show separation between epithelial cells and supporting cells which can cause damage to the integrity of the secondary lamella structure. There is no prohibition in consuming fish, because as we know fish contains very high protein. However, if it is known that the fish habitat contains high levels of heavy metals, the consumption level should be reduced or consumed in small quantities.

3.3 Bioconcentration factor in ponyfish

The BCF value illustrates the ability of biota to accumulate heavy metals in water in their environment. The BCF results of ponyfish for Cd and Cu metals in both flesh and gills have moderate accumulation values because they have values greater than 100. Bioconcentration levels of ponyfish are presented in Table 1.

Table 1. Bioconcentration factor in ponyfish flesh and gills

Organ	Cd (mg/kg)	Cu (mg/kg)
Flesh	170.86	108.31
Gills	203.3	215.17

The BCF is the ability of an organism to accumulate pollutants in its body [19]. The BCF value is obtained by comparing the ability of ponyfish to absorb heavy metals dissolved in the water. Bioaccumulation in aquatic organisms is generally influenced by heavy metal content in water, feed, fish species, excretion and metabolism. The higher the BCF value of an organism, the higher the ability of the organism to accumulate heavy metals. The water bioconcentration factor in ponyfish is presented in Table 2. The BCF value of Cd in ponyfish flesh and gills is above 100, which is 170.86 (in flesh) and 203.3 (in gills). The BCF value of Cu in flesh and gills also has a value above 100, namely 108.31 (in flesh) and 215.17 (in gills). The higher the BCF value in an organism indicates the higher the organism accumulates heavy metals.

3.4 Safe limit of consumption of ponyfish

The *Maximum Tolerable Intake* (MTI) value indicates the maximum weight in consuming food exposed to heavy metals in each week. Knowing the MTI value can be useful for minimizing the impact of heavy metals on human health. The results of the analysis of the safe consumption limit values of laying fish per weight of adults (50 kg) and children (15 kg) are presented in Table 2. The safe consumption limit values of laying fish for heavy metal Cd are 1.858 kg flesh/week (for adults) and 0.558 kg flesh/week (for children), while the safe consumption limit of laying fish for heavy metal Cu is 376.39 kg flesh/week (for adults) and 112.92 kg flesh/week (for children). The safe consumption limit of pepetek fish is presented in Table 2.

Table 2. Safe limit of consumption of ponyfish

	MTI (kg flesh/week adult (50 kg)		MTI (kg flesh/week children (15 kg)	
	Cd	Cu	Cd	Cu
MWI	0.35	175	0.105	52.5
Ponyfish	1.858	376.39	0.558	112.92

The maximum safe consumption value of a biota is determined based on the smallest limit value of the type of heavy metal content, so that there is no accumulation of heavy metals in the body that will be toxic and harmful to health. High levels of heavy metals if absorbed in the body can cause death. [20] said that the maximum consumption value can be used as a reference to reduce the negative impact of heavy metals entering the body. Based on the calculation of the MTI value, the maximum consumption limit that can be tolerated by adults for heavy metal Cd is 1.858 kg of flesh/week, and the safe consumption limit for heavy metal Cu is 376.39 kg of flesh/week. In children, the safe consumption limit for heavy metal Cd was 0.558 kg of flesh/week, and the safe consumption limit for heavy metal Cu was 112.92 kg of flesh/week. The results obtained from the study indicate that ponyfish in Cilincing Waters are not safe for consumption in large quantities. According to [21] the maximum limit of fish consumption is determined based on the smallest value because foodstuffs that already contain heavy metals even though they are fairly low if continuously consumed will accumulate in the human body and will be toxic. Heavy metal accumulation that occurs in the human body can cause various health problems such as kidney disease, hypertension, liver and lung disorders and other diseases.

4 Conclusion

The content of heavy metal Cd in flesh and gills is above the predetermined quality standard, while heavy metal Cu is below the predetermined quality standard, the accumulation rate of heavy metal Cd and Cu in ponyfish is moderate. Organs of ponyfish exposed to heavy metals experience inflammatory cell infiltration in the flesh and there is edema, secondary cell hyperplasia, basal cell hyperplasia, and lamella fusion in the gill organs. The safe consumption limit of ponyfish exposed to heavy metals Cd and Cu in adults is about 1.858 kg of flesh/week, while in children it is about 0.558 kg of flesh/week.

References

1. Peraturan Pemerintah Republik Indonesia No. 22 Tahun 2021 tentang Penyelenggaraan Perlindungan dan Pengelolaan Lingkungan Hidup (2021)
2. Hartati ST, Prihatiningsih, Awwaludin & Indarsyah IJ. 2006. Identifikasi kondisi sumberdaya dan lingkungan pada lokasi pemanfaatan lahan perikanan di Teluk Jakarta. (Laporan Tahun 2006, Jakarta : Balai Riset Perikanan Laut (2006)
3. Solichin A, IP. Sari, SW. Saputra., N. Widyorini. Dinamika populasi ikan kurisi (Nemipterus japonicus Bloch, 1791) di Perairan Teluk Semarang. PENA Akuatika : Jurnal Ilmiah Perikanan dan Kelautan. 21(2): 1-14.
4. Triharyuni S, AA. Utama., N. Zulfa., P. S. Sulaiman. Komposisi, sebaran ukuran dan hubungan panjang-berat beberapa jenis ikan petek (Leiognathidae) di Teluk Jakarta. Bawal. 9(2) : 75-83 (2017)
5. Arifin Z, Fadhlina D. Fraksinasi logam berat Pb, Cd, Cu dan Zn dalam sedimen dan biavailibitasnya bagi biota di Perairan Teluk Jakarta. Ilmu Kelautan. 14 (1): 27-32 (2009)
6. Riani E. Kontaminasi Merkuri (Hg) dalam organ tubuh ikan petek (Leiognathus Equulus) di Perairan Ancol, Teluk Jakarta. Jurnal Teknologi Lingkungan. 11(2) : 313-322 (2010)
7. Cordova MR. Zamani NP. Yulianda F. Akumulasi logam berat pada kerang hijau (Perna veridis) di Perairan Teluk Jakarta. Jurnal Moluska Indonesia. 1(1) : 1-8 (2011)
8. Jalius, Setiyanto, Sumantadinata DD, Riani E, Ernawati Y. Akumulasi logam berat dan pengaruhnya terhadap spermatogenesis kerang hijau (Perna veridis). Jurnal Ilmu-Ilmu Perairan dan Perikanan Indonesia. 15(1) : 77-83 (2008)
9. Kusuma AH, Prartono T, Atmadipoera AS, Arifin T. Sebaran logam berat terlarut dan terendapkan di Perairan Teluk Jakarta pada bulan September 2014. Jurnal Teknologi Perikanan dan Kelautan. 6(1): 41-29 (2015)
10. Sagala L. Sulistiono. Djamar TFLB. Heavy metal contents of Hg, Cd, Pb and Cu in splendid ponyfish Eubleekeria splendens (Cuvier, 1829) flesh in Bnaten Bay, Indonesia. ISFFS : 1-12 (2021)
11. Mardani NPS, Restu IW, Sari AHW. Kandungan logam berat timbal (Pb) dan kadmium (Cd) pada badan air dan ikan di Perairan Teluk Benoa, Bali. Current trends in aquatic science. 1(1): 106-113 (2018)
12. Wahyuningsih T, Rumanta M, Nurdin G. 2015. Pencemaran Pb dan Cd pada hasil perikanan laut tangkapan nelayan di sekitar Teluk Jakarta. 105-111 (2015)
13. Darmono. Logam dalam sistem biologi makhluk hidup. (Penerbit Universitas Indonesia, Jakarta (1995)
14. Rahmadani TBC, Diniariwisan D. Pencemaran logam berat Jenis Kadmium (Cd) di Perairan dan Dampak Terhadap Ikan. Jurnal Ganec Swara. 17(2) : 440-445 (2023)
15. Palar H. Pencemaran dan Toksikologi Logam Berat. (Jakarta (ID), Rineka Cipta (2012)
16. Roy SP. Overview of heavy metals and aquatic environment with notes on their recovery. Ecoscan : An International Quarterly Journal of Environmental Sciences. 4 : 235–240 (2010)
17. Authman MMN, Abbas WT, Gaafar AY. Metals concentrations in Nile tilapia Oreochromis niloticus (Linnaeus, 1758) from illegal fish farm in Al- Minufiya Province, Egypt, and their effects on some tissues structures. Ecotoxicology and Environmental Safety. 84 : 163-172 (2012)

18. Priosoeryanto BP, Ersa IM, Tiuria R, Handayani SU. Gambaran Histomorfologi insang, usus, dan otot ikan mujair (Oreochromis mossambicus) yang berasal dari daerah Ciampea, Bogor. Indonesian Journal of Veterinary Science and Medicine. 2(1) : 1-8 (2010)
19. Budiyono B, Rosahada AD, Dewanti NAY. Bio-concentration of Copper in the Oreochromis mossambicus and Safe Level of Consumption. Unnes Journal of Public Health. 10 (1): 86–93 (2021)
20. Prastyo Y, Batu DTFL, Sulistiono. Heavy Metal contain Cu and Cd on the mullet in the estuary of Donan River, Cilacap, Central Java. Indonesian Journal of Fisheries Products Processing. 20(1) : 18-27 (2017)
21. Hidayah AM, Purwanto P, Soeprobowati TR. Biokonsentrasi faktor logam berat Pb, Cd, Cr dan Cu pada ikan nila (Oreochromis niloticus Linn.) di Karamba Danau Rawa Pening. Bioma : Berkala Ilmiah Biologi. 16(1) :1–9 (2014)