Bioaccumulation of non-essential heavy metals in fish in Ir H Djuanda Reservoir, West Java

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Abstract. Ir. H. Djuanda or Jatiluhur Reservoir dam the Citarum River, a heavily polluted river. The polluted river causing the pollution of water of the reservoir as well as the contamination of aquatic biota, including fish in the reservoir. The research was conducted in July 2018. Water and sediment samples were taken from 4 stations representing parts of the Citarum River inlet, Cilalawi River inlet, and floating net cages area. Fish samples collected consist of wild fish and cultivated fish, namely carp, tilapia, and pangasius. The results showed that the concentrations of Pb, Cd, Hg, As, and Cr were not detected in reservoir water. Heavy metals of Pb, Cd, and Cr detected in the sediment were 2.56-6.12; 0.04-0.08; and 2.621-6.013 ppm respectively. Heavy metal detected in wild fish and cultivated fish were only Cr, ranged 0.039-0.205 ppm. The value of the Bio-Concentration Factor (BCF) was very low so that the fish belongs to the low accumulate category of heavy metals and therefore, it was safe for consumption.

Keywords: bioaccumulation; fish; heavy metal; Ir. H. Djuanda Reservoir

1. Introduction
The Citarum River is one of the dirtiest rivers in the world. Various study results have been published stating that the Citarum River has been heavily polluted so that the environmental carrying capacity or water pollution loads has been exceeded [1]. Heavy metals in fishery products are one of the issues and problems that are of concern now. The existence of Citarum River pollution will affect the waters in the three reservoirs and the biota that live in them. The input of wastewater such as industrial waste, agricultural and livestock waste, fishery waste, and household waste can affect the quality of the products produced from the three reservoirs, especially the quality of fish.

Ir. H. Djuanda Reservoir is a cascade reservoir that dams the Citarum River. There are two reservoirs upstream of the river, namely Cirata Reservoir, and Saguling Reservoir. As the two upstream reservoirs, this reservoir is also used for fishery activities, both capture fisheries, and aquaculture. The water quality of the reservoir is influenced by an internal source such as aquaculture through floating net cages and external sources such as inputs from rivers.

Bioaccumulation is defined as the process of certain toxic substances (such as heavy metals) that are present in the environment and accumulate in the body of organisms [2, 3]. Essential heavy metals such as copper (Cu), selenium (Se), iron (Fe), and zinc (Zn) are important for maintaining human metabolism if it is not excessive. But if excessive, it will cause toxicity to the body. Metals which are microelements...
are a nonessential group of heavy metals that have no function at all in the body. The metal is even very dangerous and can cause poisoning (toxic) to humans, namely: Lead (Pb), mercury (Hg), arsenic (As), and cadmium (Cd) [4]. Heavy metals in water bodies can precipitate at the bottom or absorption by organisms. Precipitation occurs when the heavy metal concentration is greater than the solubility. Precipitated heavy metals may increase or decrease depending on environmental conditions. Water with low oxygen due to organic matter pollution causes heavy metals to settle easily [5]. Therefore, this study aims to determine the concentration of non-essential heavy metals (Pb, Cd, Hg, As, and Cr) in the waters and bioaccumulation in fish in the Ir. H. Djuanda Reservoir.

2. Methods
The research was conducted in April 2018 at the Ir. H. Djuanda. Water and sediment sampling was carried out at 4 stations representing the reservoir inlet (Cilalawi and Galumpit) and floating net cage culture location (Astab and Pasir Jangkung) (figure 1). A sampling of cultured fish is carried out in cage culture floating net collectors, while wild fish sampling is carried out by experimental gillnet and caught of fisherman. The fish feed analyzed is widely used by the farmer. Analysis of non-essential heavy metals in fish feed to determine the concentration of these heavy metals in the fish feed which is mostly provided by farmers. Non-essential heavy metals Cd, Pb, Hg, As, and Cr in water were analyzed by 18-10-11/MU/SMM-SIG. ICP.OES method, in fish meal and fish feed by 18-13-1/MU/SMM-SIG. ICP.OES method and in sediment by 18-13-14/MU/SMM-SIG.ICS.EOS method. Non-essential heavy metal analysis in water, sediment, fish, and feed was carried out in Saraswanti Indo Genetech (SIG).

![Figure 1. Map of Ir. H. Djuanda Reservoir.](image_url)
Muzyed [6] states that the Bio-Concentration Factor (BCF) is used to determine how many multiples the metal concentration in meat comes from the environment. Determination of BCF based on the formulation of LaGrega et al. [7].

\[
\text{BCF} = \frac{C_{\text{org}}}{C}
\]

where,

- **BCF**: Bio-Concentration Factor
- **\(C_{\text{org}}\)**: Heavy metal concentration in organisms (mg/kg or ppm)
- **\(C\)**: Heavy metal concentration in water (ppm)

Criteria of BCF based on calculation divided into three categories are BCF > 1000 is the high accumulative category; BCF 100-1000 is medium accumulative category and BCF < 100 is a low accumulative category [7].

3. Results and discussion

3.1. Heavy metal concentrations in water, fish feeds, and sediment

Heavy metals enter the aquatic environment in two ways, the first naturally, such as due to bedrock erosion, windblown dust, volcanic activity, and fires, and the second anthropogenically, such as waste from industry, agriculture, and urban activities [8]. It is feared that the input of waste into the waters will affect the quality of fish production. Waste containing heavy metals can cause the accumulation of heavy metals in fish that live in these polluted waters. The content of heavy metals in fish meat is closely related to food safety, because if the meat has been contaminated with heavy metals, then humans who consume the fish have the potential to accumulate heavy metals in their bodies. Food safety is a condition and necessary measures to prevent food from possible contamination of biological, chemical, and other objects that can disturb, harm, and endanger human health (Government Regulations No. 28 Year 2004).

Table 1 shows that the concentrations of non-essential heavy metals (Pb, Cd, Hg, As, and Cr) in the waters are so low that they are undetectable. However, the concentrations of non-essential heavy metals Pb, Cd, and Cr were found in aquatic sediments and fish feed. This finding in the Djuanda Reservoir is in contrast to the heavy metal concentrations detected in Lake Unhas, Makasar, and in the two upstream reservoirs. In the waters of Lake Unhas, Pb and Cr have exceeded the quality standard value, i.e. 3.9 mg/L and 0.4 mg/L respectively [9]. In Rawa Pening, a lake in Central Java, Cd concentrations were detected ranging from 0.005 to 0.008 mg/L; Cr was 0.03 mg/L and Pb was 0.03 mg/L [2]. In the Citarum Cascade Reservoir, heavy metals were also detected. In Saguling Reservoir water Pb was detected in the range of 0.0005-0.0421 mg/L [10] and Cd of about 0.004-0.124 mg/L [11]. In Cirata Reservoir Pb was 0.036 mg/L; Cd was 0.032 mg/L; Cr was 0.045 mg/L and Hg was 0.011 mg/L [12].

### Table 1. The concentration of non-essential heavy metals in water, sediment, and fish feeds.

| No | Sample                  | Pb (ppm) | Cd (ppm) | Hg (ppm) | As (ppm) | Cr (ppm) |
|----|-------------------------|----------|----------|----------|----------|----------|
| 1  | Water                   | nd-0.07  | nd       | nd       | nd       | nd       |
| 2  | Sediment                | 2.56-6.12| 0.04-0.08| nd       | nd       | 2.621-6.013|
| 3  | Fish Feeds              | nd-0.45  | nd-0.08  | nd       | nd       | 0.947-1.708|
|    | Quality Standard         |          |          |          |          |          |
| 1  | Water for fisheries     | 0.03     | 0.01     | 0.002    | 0.01     | 0.05     |
|    | activity (Class of 3) * |          |          |          |          |          |
| 2  | Sediment**              | 20       | 50       | 0.15     | 1.5      | 80       |

**nd:** not detected

Limit detected in water and sediment (ppm) Pb = 0.00086; Cd = 0.00011; Hg = 0.0002; As = 0.00004; Cr = 0.0012

Limit detected in meat and fish feed (ppm) Pb = 0.009; Cd = 0.00011; Hg = 0.004; As = 0.008

* Government Regulations No 82 Year 2001;

** Ranged value of New Zealand Environment and Conservation Council (ANZECC) [9]
Chromium heavy metal is a carcinogen. Cr metal is sourced from nature and due to anthropogenic activities. Natural sources of Cr include volcanic eruptions, weathering of rocks, soil, and sediment while anthropogenic activities include burning fossil fuels, producing chromate dyes or paints, making plastics, paper, making pulp, rubber, metal coating, and tanning skin [13]. Inputs Cr metal to the waters through air deposition, surface runoff which then bonds with particles and deposited in bottom sediments [14]. The concentration of Cr in the sediment is still below the threshold and it is suspected that the source of Cr is a result of rock weathering as happened in the Al Mujib reservoir at Jordan [8] and also fish feed. Cr in the fish feed was found to range 0.947-1.708 ppm. According to Puteri et al. [15] adding chromium to feed will accelerate the absorption of feed that enters the body. The addition of 6 mg/kg Cr was able to increase the efficiency of feed utilization and the relative growth rate for catfish (Clarias sp) [15] and 3-4.5 mg/kg for climbing pearch (Anabas testudineus) [16]. Chromium in feed can increase the efficiency of carbohydrates and lipids to ensure energy supply as a result, fish growth is faster [16].

Cadmium includes dangerous heavy metals that are non-degradable and persistent. This metal can cause several symptoms of itai-itai, kidney damage, hypertension, and emphysema. Sources of Cd metal from wastewater, agricultural fertilizers, and geological factors [14]. The concentration of Cd in the sediment is still below the threshold and is thought to have originated from pollution and reservoir geological factors. Heavy metal Pb is toxic and can accumulate in bones and can affect the nervous system. Sources of Pb include domestic waste, industrial waste (industrial waste from car tires, paint, batteries, and cosmetics), and agricultural fertilizer waste. Also, reservoir geological factors can affect the concentration of Pb in the water column and sediment [14]. The Pb concentration in the sediments of the Djuanda Reservoir is still below the threshold. Yusuf's [17] study showed that the 3 brands of freshwater fish feed analyzed contained non-essential heavy metals Hg and As.

Sediment is a heavy metal absorber in aquatic ecosystems. Heavy metals are non-biodegradable and can be adsorbed by sediment particles or accumulate in aquatic organisms. Heavy metal pollution can increase the vulnerability of aquatic animals to various diseases by disrupting immune function, reproduction, and development processes [18]. The concentration of heavy metals in the sediments detected in the Djuanda Reservoir was Cr> Pb> Cd. Water quality can affect the presence of heavy metals in water. High metal content in fish and shrimp flesh is not only influenced by the metal content in water, but also by pH, temperature, salinity. High temperatures will increase metal accumulation because the metabolic rate increases. Also, other factors that influence the accumulation of heavy metals in fish are food and sediment contamination. The concentration of heavy metals in aquatic animals varies depending on the ability to absorb and excrete heavy metals around these waters [19].

### 3.2. Non-essential heavy metal concentration in fish and bio concentration factor

The results of the analysis of non-essential heavy metals in fish meat caught and cultured are presented in table 2.s

#### Table 2. The concentration of non-essential heavy metals on some fishes from Ir. H. Djuanda Reservoir.

| No | Sample                                      | Pb (ppm) | Cd (ppm) | Hg (ppm) | As (ppm) | Cr (ppm) |
|----|---------------------------------------------|----------|----------|----------|----------|----------|
| 3  | Wild of tilapia                             | nd       | nd       | nd       | nd       | 0.074-0.205 |
| 4  | Tilapia from floating net cage culture      | nd       | nd       | nd       | nd       | 0.074    |
| 5  | Wild of Carp                                | nd       | nd       | nd       | nd       | 0.064-0.13 |
| 6  | Carp from floating net cage culture         | nd       | nd       | nd       | nd       | 0.089    |
| 7  | Wild of Pangasius                           | nd       | nd       | nd       | nd       | 0.039-0.138 |

Quality Standard

| 1  | Fish and processing products*              | 0.25     | 0.2      | 0.06     | 0.1      |
| 2  | Predatory fish*                            | 0.4      | 0.4      | 0.3      |

nd: not detected

* Regulation of Indonesian Food and Drug Authority No. 23 Year 2017
Referring to the Regulation of Indonesian Food and Drug Authority (BPOM) No. 23 Year 2017 concerning the maximum limit of heavy metal contamination in processed food. Table 3 shows that the concentrations of non-essential heavy metals Pb, Hg, Cd, and As were not detected in carp, tilapia, and pangasius, both wild and cultured fish. However, low Cr was detected in fish samples. The presence of Cr in the wild fish was presumed from natural food and sediment also possibly consumed the left over fish feeds from the cage culture. While the cultivated fish was presumed from the fish feed. Several trademarks of fish feed were detected to contain heavy metal Cr was presumed from the feed raw material. Wicaksono et al. [20] suspect that heavy metal Pb in Cirata Reservoir can come from fish feed contaminated with Pb metal. This is based on the results of BPWC monitoring in 2014 which states that the fish feed in the Cirata Reservoir contains Pb metal with an average of 1.162 mg/kg. The magnitude of the concentration of heavy metals in fish depends on the time of the fish in the location of heavy metal contamination. The results of Yulaipi and Ainurohim's [21] research showed that exposure duration of Pb had a significant effect on Pb bioaccumulation in tilapia fish. Paundanan et al. [22] state that the heavy metal content in fish is accumulative. This means that the heavy metal content in the fish's body will increase over time depending on the duration of exposure to the fish.

Referring to the Dirjen POM No. 03725 / B / SK / 89 which states that the limit for heavy metal Cr in food is 2.5 ppm [23], so the fish caught and cultivated in the Djuanda reservoir are still below this threshold and safe for consumption. Symptoms of Cr poisoning in the body are nausea, stomach pain, ulcers, respiratory problems, weak immune system, kidney and liver damage, changes in genetic material, lung cancer, and death [26]. The toxic effects of Cr on freshwater fish can cause hematological disorders and immune responses [13]. Previous research in this reservoir [26] resulted that nilem fish in floating net cages culture contained Pb about 0.1-0.12 ppm; Cd about 0.011-0.254 mg/L and Hg in the range of 0.000925-0.00325 mg/L.

Based on the concentration of heavy metals in water and fish, it is shown that the Bio-Concentration Factor (BCF) was undetected or very low. So that, the fish was low accumulative category because the availability of heavy metals in water was very low to not detected. It means carp, tilapia, and pangasius from Ir. H. Djuanda reservoir was safe for consumption. Accumulation of heavy metals in the body of organisms depends on the concentration of heavy metals in water/environment, temperature, pH, and dissolved oxygen. As for comparison, the results of research in Rawa Pening showed that cultivated tilapia had BCF values of Pb ranged from 3.67-6; Cd ranged 1.25-2 and Cr ranged 4.33-5.33, and categorized as having a low accumulation of heavy metals in its body [2].

Supian and Salami [26] stated that in carp and tilapia from floating net cage culture and wild red devils in Ir. H. Djuanda contains the heavy metal Hg in small concentrations and is still safe for consumption. The source of Hg is thought to have come from fish feed and the results of the study indicated that fish feed contained Hg ranging from 0.18 x 10^{-6}-4.48 x 10^{-6} mg/kg. Meanwhile, the results of 2018 observations of the five brands analyzed did not contain the element Hg. The number of brands analyzed was less compared to those circulating in cultivators. Namely, around 10-17 brands [26] and some farmers who had little capital used expired bread and noodles.

4. Conclusion

The water of Ir. H. Djuanda Reservoir contained undetected or very low Hg, Cd, As, and Cr. However, Pb, Cd, and Cr were detected in the sediment, namely in the range of 2.56-6.12, 0.04-0.08 and 2.621-6.013 ppm. The concentration of heavy metals in the sediments detected in the Djuanda Reservoir was Cr > Pb > Cd. Bio-Concentration Factor (BCF) was undetected or very low. Carp, tilapia, and pangasius fish from Ir. H. Djuanda reservoir were safe for consumption.

References

[1] Yusuf M, Elfghi F M, Zaidi S A, Abdullah E C and Khan M A 2015 Applications of graphene and its derivatives as an adsorbent for heavy metal and dye removal: A systematic and comprehensive overview RSC Advances 5(62): 50392-50420
[2] Hidayah A M P and Soeprobowati T R 2014 Bioconcentration of Heavy Metal Factors Pb, Cd, Cr and Cu in Tilapia (*Oreochromis niloticus* Linn.) At Rawa Pening Lake Karamba (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

[3] Javed M and Usmani N 2017 An Overview of the Adverse Effects of Heavy Metal Contamination on Fish Health *Proc. Natl. Acad. Sci., India. Sect. B Biol. Sci.* DOI 10.1007/s40011-017-0875-7

[4] Agustina T 2014 Heavy Metal Contamination In Food And Its Impact On Health (Kontaminasi Logam Berat Pada Makanan Dan Dampaknya Pada Kesehatan) *Teknobuga* **1** (1): 53-65

[5] Budiati S, Dewi N K and Pribadi T A 2014 Accumulation of Chromium (Cr) Heavy Metal Content in Betok Fish (*Anabas Testudineus*) Exposed to Textile Liquid Waste in Langsur River. Sukoharjo (Akumulasi Kandungan Logam Berat Chromium (Cr) pada Ikan Betok (*Anabas Testudineus*) yang Terpapar Limbah Cair Tekstil di Sungai Langsur Sukoharjo) *Unnes J Life Sci* **3**(1)

[6] Muzyed S K I 2011 Heavy metal concentrations in commercially available fishes in Gaza strip markets *Department of Chemistry, Deanyer of Higher Studies, Faculty of Science, The Islamic University - Gaza*

[7] LaGrega M D, Buckingham P L and Evans J C 2001 *Hazardous Waste Management. Second Edition* (New York: McGraw Hill International Edition)

[8] Manasreh W, Hailt I and El-Hasan T M 2010 Heavy metal and anionic contamination in the water and sediments in Al-Mujib reservoir, central Jordan *Environ Earth Sci* **60**: 613-621

[9] Yaqin K, Karim Y and Fachruddin L 2018 Water Quality and Content of Several Metals at Lake Unhas (Kualitas Air dan Kandungan Beberapa Logam di Danau Unhas) *Jurnal Pengelolaan Perairan* **1**(1): 1-13

[10] Adani J E, Wardhani E and Pharmawati K 2018 Identification of Lead (Pb) and Zinc (Zn) Heavy Metal Pollution in Surface Water and Sediment in Saguling Reservoir. West Java Province (Identifikasi Pencemaran Logam Berat Timbal (Pb) dan Seng (Zn) di Air Permukaan dan Sedimen Waduk Saguling Provinsi Jawa Barat). *Reka Lingkungan Jurnal Online Institut Teknologi Nasional* **6**(2): 1-12

[11] Wardhani E, Roosmini D and Notodarmojo S 2016 Cadmium Pollution in the Sediment of Saguling Reservoir, West Java Province (Pencemaran Kadmium di Sedimen Waduk Saguling Provinsi Jawa Barat) *J. Manusia dan Lingkungan* **23**(3): 285-294

[12] Ryani E 2014 Fish Heavy Metal Contamination in Floating Net cages culture at Cirata Reservoir (Kontaminasi Logam Berat pada Ikan Budidaya dalam Lokasi Tangkai Jaring apung di Waduk Cirata) *Jurnal Teknobiga* **5**(1): 51-61

[13] Vitasari M, Darundiati Y H and Setiani O 2020 Bioconcentration of Heavy Metal Chromium Hexavalent (Cr VI) Factors in Tilapia (*Oreochromis niloticus*) at Tenggang River. East Semarang (Biokonsentrasi Faktor Logam Berat Kromium Heksavalen (Cr VI) Pada Ikan Nila (*Oreochromis niloticus*) di Sungai Tenggang Semarang Timur) *Jurnal Ilmiah Mahasiswa* **10**(1): 1-9

[14] Bazrafshan A, Mostafapoura F K, Esmaelnejad M, Ebrahimzadehc G R and Mahvid A H 2015 The concentration of heavy metals in surface water and sediments of Chah Nimeh water reservoir in Sistan and Baluchestan province, Iran *Desalination and Water Treatment* **57**(20): 1-11

[15] Puteri B J, Subandiyono and Hastuti S 2020 Role of Chromium (Cr⁶⁺) in Artificial Feed on the Efficiency of Utilization Feed and the Growth of Catfish (*Clarias* sp.) (Peran Kromium (Cr⁶⁺) dalam Pakan Buatan terhadap Tingkat Efesiensi Pemanfaatan Pakan dan Pertumbuhan Lele (*Clarias* sp.)) *Jurnal Sains Akuakultur Tropis* **4**(2): 161-70

[16] Akbar J, Adriani M and Aisiah S 2011 The Effect of Contain Chromium (Cr⁶⁺) at Various Levels of Salinity on the Growth of Climbing Perch (*Anabas testudineus*) (Pengaruh Pemberian Pakan yang Mengandung Berbagai Level Kromium (Cr⁶⁺) pada Salinitas yang Berbeda
terhadap Pertumbuhan Ikan Betok (Anabas testudineus)) Bioanatutra-Jurnal Ilmu-ilmu Hayati dan Fisik 13(2): 248-54

[17] Yusuf S 2014 Applications of NAA Technique at RSG-Gas Reactor on Determination of Essential and Toxic Elements in Fish and Fish Feed (Aplikasi Teknik AAN di Reaktor RSG-Gas pada Penentuan Unsur Eensial dan Toksik di dalam Ikan dan Pakan Ikan) J. Tek. Reaktor. Nukl. 16(1): 44-55

[18] Adebayo I A 2017 Determination of Heavy Metals in Water. Fish and Sediment from Ureje Water Reservoir Fish & Ocean Opj. 4(1): 001-4

[19] Andini A and Ainuiyah S D 2018 Relationship of Cr Levels in Pond Water to Cr in Tilapia (Oreochromis niloticus), Milkfish (Chanos chanos) and Vanname Shrimp (Litopenaeus vannamei) in the Jabon Sidoarjo Region (Hubungan Kadar Cr dalam Air Tambak terhadap Cr Pada Ikan Nila (Oreochromis niloticus), Ikan Bandeng (Chanos chanos) dan Udang Vaname (Litopenaeus vannamei) di Kawasan Jabon Sidoarjo) Medicra (Journal of Medical Laboratory Science/Technology) 1(1): 7-14

[20] Wicaksono E A S and Walim L 2016 Distribution of Heavy Metal Lead (Pb) in Macrozoobenthos in Cirata Reservoir, West Java Province (Sebaran Logam Berat Timbal (Pb) pada Makrozoobenthos di Perairan Waduk Cirata, Provinsi Jawa Barat) Jurnal Perikanan Kelautan VII(1): 103-114

[21] Yulaipi S and Aunurohim 2013 Bioaccumulation of Lead (Pb) and Its Relationship with the Growth Rate of Tilapia Fish (Oreochromis mossambicus) (Bioakumulasi Logam Berat Timbal (Pb) dan Hubungannya dengan Laju Pertumbuhan Ikan Mujair (Oreochromis mossambicus)) Jurnal Sains Dan Seni Pomits 2(2): 2337-3520

[22] Paundanan M, Sitti F and Rikwan 2020 Heavy Metal Content (Hg, Pb) and Histopathology (Gills, Meat, Liver, Spleen) of Selar Tetengkek (Megalaspis cordyla L) at Palu Bay (Kandungan Logam Berat (Hg, Pb) dan Histopatologi (Insang, Daging, Hati, Limpa) Ikan Selar Tetengkek (Megalaspis cordyla L) di Teluk Palu) Envoist Journal 1(1): 1-12

[23] Prastyo D, Titin H and Iskandar 2016 Bioaccumulation of Metal Chromium (Cr) in Gills, Liver, and Fish Meat Caught Upstream of the Cimanuk River, Garut Regency (Bioakumulasi Logam Kromium (Cr) pada Insang, Hati, dan Daging Ikan yang Tertangkap di Hulu Sungai Cimanuk Kabupaten Garut) Jurnal Perikanan Kelautan VII (2): 1-8

[24] Priyadi H, Iskandar R, Nuryati R, Rofatin B and Sumarsih E 2007 Science and Technology for the Community of Sukaregang Garut Facing the Problem of Wastewater from the Leather Tanning (Iptek Bagi Masyarakat (Ibm) Sukaregang Garut Yang Menghadapi Masalah Air Limbah Industri Penyamakan Kulit) Penelitian Bersama (Garut: Universitas Siliwangi)

[25] Pratiwi, Rostika R and Dhahiyyat Y 2011 Effect of Feeding Rate on Growth Rates and Heavy Metal Deposition in Patchouli Fish in Floating Net Cages in Ir. H. Djuanda Reservoir (Pengaruh Tingkat Pemberian Pakan terhadap Laju Pertumbuhan dan Deposisi Logam Berat pada Ikan Nilem di Karamba Jaring Apung Waduk Ir. H. Djuanda) Jurnal akuatika II(2)

[26] Suprian C and Salami IRS 2011 Accumulation of Mercury (Hg) in Fish Cage Cultivation of Floating Net Cages and Wild Fish in Jatiluhur Reservoir (Akumulasi Merkuri (Hg) Pada Ikan Budidaya Keramba Jaring Apung Dan Ikan Liar Di Waduk Jatiluhur) Jurnal Teknik Lingkungan 17(2):68-76

**Declarations of author contribution**

Lismining Pujiyani Astuti, Andri Warsa, Didik Wahju Hendro Tjahjo, and Amula Nurfiarini contributed as the main contributor to this paper. All authors read and approved the final paper.