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THE QUANTIFICATION OF LEAD HEAVY METALS LEVELS ON MUJAIR FISH (*Oreochromis mossambicus*) ORGANS FROM BRANTAS AND BENGAWAN SOLO RIVER, EAST JAVA PROVINCE, INDONESIA

KUANTIFIKASI KADAR LOGAM BERAT TIMBAL PADA ORGAN IKAN MUJAIR (*Oreochromis mossambicus*) DARI SUNGAI BRANTAS DAN BENGAWAN SOLO JAWA TIMUR INDONESIA

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Abstract

Oreochromis mossambicus (*O. mossambicus*) frequently found in the Brantas and Bengawan Solo rivers, Java island, Indonesia. However, heavy metals produced from anthropogenic activities can enter the water and accumulate in organisms living in the river. This study aimed to determine the lead (Pb) heavy metal in the gills, flesh, and intestines of *O. mossambicus* living in the two aforementioned rivers and to measure the Pb levels in each river. The results showed that the Pb in the *O. mossambicus* organs in the Bengawan Solo river was as follows 3.159 mg/kg in the gills; 1.930 mg/kg in the intestine; and 2.511 mg/kg in flesh, while in the Brantas river it was follows 1.600 mg/kg in gills; 1.402 mg/kg in the intestine; and 1.455 mg/kg flesh. Pb levels in each river water were 0.568 mg/mL in the Brantas river and 0.525 mg/mL in the Bengawan Solo river. Based on the data obtained, it can be concluded that the Pb content in fish organs and river water has exceeded the quality standard for Pb levels according to the government regulation No.82 2001 (SNI 7387:2009), that is, 0.3 mg/kg in organs and 0.03 mg/L in water. The results of this study are expected to be a concern for the authorities in order to revitalize the river to restore the function and support the survival of river biota.

Keywords: Bengawan Solo river; Brantas river; Fish organs; Lead; *Oreochromis mossambicus*

Abstrak

Ikan mujair (Oreochromis mossambicus) banyak ditemukan di sungai Brantas dan Bengawan Solo, namun aktivitas antropogenik yang menghasilkan logam berat dapat masuk ke perairan sehingga terakumulasi dalam organisme yang hidup di perairan tersebut. Penelitian ini bertujuan untuk mengetahui kandungan logam berat timbal (Pb) pada insang, daging, dan usus pada O. Mossambicus yang hidup di kedua sungai tersebut serta mengukur kandungan Pb pada masing-masing air sungai. Hasil penelitian menunjukkan bahwa kandungan Pb pada organ O. mossambicus di sungai Bengawan Solo adalah sebagai berikut 3.159 mg/kg pada insang; 1.930 mg/kg di usus; dan 2.511 mg/kg pada daging, sedangkan di sungai Brantas adalah sebagai berikut 1.600 mg/kg pada insang; 1,402 mg/kg pada usus; dan 1,455 mg/kg pada daging. Kadar Pb pada masing-masing air sungai adalah 0,568 mg/mL (sungai Brantas) dan 0,525 mg/mL (sungai Bengawan Solo). Berdasarkan data yang diperoleh dapat disimpulkan bahwa kandungan Pb pada organ ikan maupun air sungai sudah melebihi baku mutu kadar Pb pada organ yaitu 0,3 mg/kg (SNI 7387:2009) dan 0,03 mg/L pada perairan (PP No.82 tahun 2001). Hasil penelitian ini diharapkan dapat menjadi perhatian pihak-pihak terkait agar dapat melakukan revitalisasi sungai guna mengembalikan fungsi dan mendukung keberlangsungan hidup biota sungai.

***Kata kunci**: Oreochromis mossambicus; Organ ikan; Sungai Bengawan Solo; Sungai Brantas; Timbal*

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INTRODUCTION

The decline in water quality as a result of pollution can affect human life and the aquatic biota in it. The Brantas river and the Bengawan Solo river are the two largest rivers on the island of Java, Indonesia which are also vulnerable to various pollutions due to massive human activities. Pollution in water is commonly found in the form of heavy metal contamination, one of which is lead (Pb) (Briffa et al., 2020). Lead pollution is caused by industrial activities, agriculture, and increased use of leaded gasoline, and is exacerbated by excessive waste disposal in watersheds (Vareda et al., 2019).

The high concentration of lead heavy metal waste pollution is very dangerous for river biota including fish which is frequently consumed by people around the river. Increased levels of heavy metal pollution in water will be poisonous and cause toxic effects on biota (Herliwati et al., 2022; Briffa et al., 2020). Thus, heavy metal which is initially needed for metabolism will harm humans. Heavy metals ingested by humans will be distributed through the blood circulation, then absorbed by the kidneys, brain, and stored in bones and teeth (Balali-mood et al., 2021). According to Jaishankar et al. (2014) heavy metal contamination in children can cause decreased brain function and delayed growth and development.

One of the most eaten freshwater fish by people around the Brantas and Bengawan Solo rivers is Mujair (*Oreochromis mossambicus*). In a study conducted by Manggara and Prasongko (2015) on the measurement of lead (Pb) levels of tilapia (*Oreochromis. sp*) originating from the Semampir village on the Brantas river, Kediri, stated that Pb level was (0.4864 ± 0.0493) mg/kg and did not meet the requirements for heavy metal contamination of Pb in fish according to SNI 7387:2009 of 0.3 mg/kg. Based on research conducted by Hayati et al. (2017), it was found that lead (Pb), chromium (Cr), copper (Cu), and cadmium (Cd) in the upstream and downstream flows of the Brantas river exceeded the quality standard.

Heavy metal pollution was also found in the Bengawan Solo river. Based on monitoring of Bengawan Solo river in 2016 that conducted by Sari (2016) there are several metals exceeded the highest quality standards including chlorine and nitrite. Heavy metal content of Cd and Pb was also found in milkfish (*Chanos chanos*) in the downstream area of the Bengawan Solo river, the accumulation of heavy metal content of Pb was mostly found in the gills of 0.170 ppm. The impact of pollution by heavy metals on fish can be viewed from various aspects such as in the organs. Fish organs contaminated by heavy metals at high concentrations will experience changes in cell and tissue structure (Jaber et al., 2021). According to Bawuro et al. (2018) the largest accumulation of heavy metals in fish occurs in the gills and liver.

Based on the abovementioned explanation, the purpose of this study was to analyze the distribution of Pb in *O. mossambicus* and water in both rivers. This is important to monitor the impact of environmental changes in the Bengawan Solo and Brantas rivers caused by heavy metal waste on the physiological conditions of the biota in them.

MATERIALS AND METHODS

Fish sampling was carried out at the downstream area of Bengawan Solo River (HBS) and the downstream area of Brantas River (HB) from August until September 2022. The geographic coordinates of the HBS sampling point were at S 6°51'23.43" E 112°31'42.35" while HB's coordinates were at S 7°19'22.78" E 112°50'29.41". Each estuary was divided into three sampling point sites. The HBS was taken at several estuaries including Leweyan (MBS1), Lebakan (MBS2), and Kalianyar (MBS3). The HB was also taken at several estuaries which include Gunung Sari (MB1), Muara Jagir (MB2), Muara Jagir (MB2), and Wonorejo (MB3) (Figure 1). The parameter measurement was carried out at the Biology Laboratory, University of Muhammadiyah Lamongan.

Fish sampling was carried out once at each sampling point in each river estuary. Ten samples were taken using fishing nets. The fish's body length was measured, and then dissected on the spot. Three organs including gills, intestines, and flesh were taken to be further analyzed.

The fish organs were cleaned and washed. Then, they were crushed, and placed in a sterile closed container. The samples were placed on a petri dish and dried in an oven at 105 °C for 18 hours. After drying, the samples were pulverized again into powder and stored until the measurement of Pb metal content was carried out.

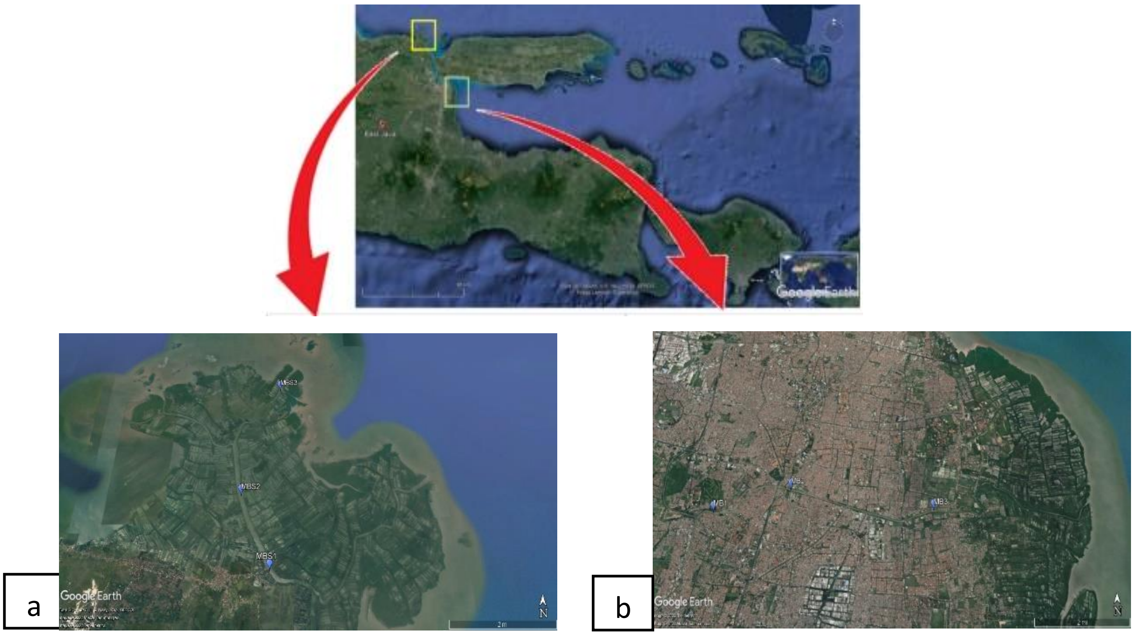

Figure 1. Sampling sites downstream area of the Bengawan Solo river (HBS) (a) dan downstream area of the Brantas river (HB) (b)

The Measurement of Pb Level in the Fish Organs

Each organ sample was weighed as much as 1 g. Then, it was put into a round bottom flask and added with 10 mL of HNO_3 : $H2O_2$ (5 : 5 mL) and digested under reflux at 100 °C for 3 hours. Furthermore, the solution resulting from the digestion was cooled at room temperature and filtered with Whatman paper No. 42. The obtained filtrate was put into a 50 mL volumetric flask, diluted with sterile distilled water to the mark, and analyzed for Pb and Cu levels using AAS. The absorbance values obtained were plotted in a standard curve to determine the concentration of the sample solution in mg/kg dry weight of the sample. Metal content= (metal concentration - blank concentration) (mg/L) x volume of sample solution (mL)/ weight of sample (mg).

The Measurement of Pb Level in the River Water

A total of 100 mL of river water taken from each sample point was added with 5 mL of concentrated HNO_3. The sample was heated on a hot plate slowly until the sample volume at each sample point was around 10–20 mL. Next, the dilution was carried out by inserting the sample into a 100 mL volumetric flask and was added by distilled water until it reached the limit and homogenized (SNI 6989.8:2004). The prepared samples were then analyzed using the Atomic Absorption Spectroscopy (AAS) instrument. To determine the levels of heavy metals in river water, the researchers applied the following formula (Hashim et al., 2014), heavy metals level (mg/L) = C_{reg} x P x V1/V2. C_{reg}= concentration read (mg/L); P= dilution factor; V1= measured sample volume (L); V2= dissolved sample volume (L).

The Measurement of River Water Pollution Parameters

River water pollution parameters were used as secondary data. The parameters measured included pH, salinity, temperature, biological oxygen dissolve (BOD), and chemical oxygen dissolve (COD). Measurements of pH, temperature, BOD, and salinity were carried out using a pH meter, thermometer, DO meter, and salinometer while COD used the titration method. BOD and COD values are expressed in milligrams per liter (mg/L). The BOD value is obtained from the difference between the initial dissolved oxygen (DO) content and the final dissolved oxygen (day 5) (DOi - DO5).

Data Analysis

The heavy metal Pb was shown in the form of diagrams and analyzed comparatively by comparing to the established quality standards. The content of heavy metals in water was compared with the water quality standard according to the government regulation No. 82 of 2001. The content of heavy metals in organs was compared with the quality standard of the National Standard Agency for Consumption Safe Limit, 2009.

RESULTS

Based on the observations on water quality parameters in the downstream area of the Bengawan Solo river, the pH value was 5.5, the temperature was 31.5 °C; the salinity was 1 ppt; the COD was 40.421 mg/L; and the BOD was 12.367 mg/L (Table 1). In the Brantas river, the pH value was 6.0, the temperature was 31.8 °C, the salinity was 0 ppt, the OD was 37.964 mg/L, and the BOD was 10.387 mg/L (Table 1). The results indicated that the quality the Bengawan Solo river water were classified as highly polluted because the upstream area was polluted.

Table 1. The condition of river water quality

Parameters	Units	Quality standards	River Sites	
			Bengawan Solo	Brantas
pH	-	6–9	5.5	6.0
Salinity (freshwater)	ppt	0–5	1	0
Temperature	°C	Deviation 3	31.5	31.8
COD	mg/L	50	40.421	37.964
BOD	mg/L	6	12.367	10.387

Table 2. Lead (Pb) pollution status in *Oreochromis mossambicus* organs in the Bengawan Solo river

Samples	Average Pb content (mg/kg)	Quality standard limit (mg/kg)	Source	Status
Gill	1.600	0.3	Safe limit for consumption of SNI 7387:2009	Exceeding
Flesh	1.455	0.3	Safe limit for consumption of SNI 7387:2009	Exceeding
Intestine	1.402	0.3	Safe limit for consumption of SNI 7387:2009	Exceeding

Table 3. Lead (Pb) pollution status in *Oreochromis mossambicus* organs in the Brantas river

Samples	Average Pb content (mg/kg)	Quality standard limit (mg/kg)	Source	Status
Gill	3.159	0.3	Safe limit for consumption of SNI 7387:2009	Exceeding
Flesh	2.511	0.3	Safe limit for consumption of SNI 7387:2009	Exceeding
Intestine	1.930	0.3	Safe limit for consumption of SNI 7387:2009	Exceeding

The results of the measurement of heavy metal levels showed that there were a number of Pb in all organs of *O. mossambicus* which had different contents and all of them exceeded the appropriate food quality standards (Tables 2 & 3). This is reinforced by the Pb content in each river water which also exceeded the water quality standard (Table 4). The average fluctuation of the Pb content found in each fish organ was included in the high category (Figure 2). The sequence pattern of Pb bioaccumulation in fish organs from high to low was intestine > gill > flesh.

Table 4. Lead (Pb) pollution status in the water of Brantas and Bengawan Solo rivers

Samples	Average Pb content (mg/L)	Quality standard limit (mg/L)	Source	Status
Brantas river water	0.568	0.03	Government regulation no. 82 of 2001	Exceeding
Bengawan Solo river water	0.525	0.03	Government regulation no. 82 of 2001	Exceeding

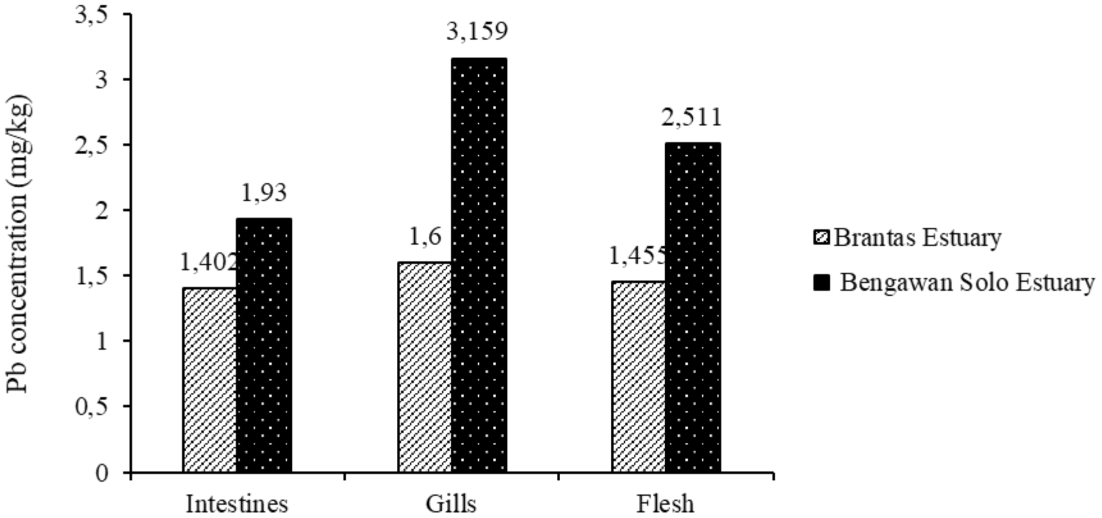

Figure 2. Diagram of the average heavy metal content of Pb in the intestines, gills and flesh of mujair fish (*Oreochromis mossambicus*) in the Brantas River estuary and Bengawan Solo estuary

DISCUSSION

Based on water quality monitoring data in the upstream area of the Bengawan Solo river in 2022, it was obtained a pH value of 6.86, the BOD was 6.07 mg/L, the temperature was 30.2 °C, and the COD was 18.5 mg/L (Aida et al., 2022). A study from Roestamy and Ali (2021) was reported on the parameter values used to assess the status of water quality in the upstream area of the Brantas River including pH of 7.2, COD of 19–23 mg/L, and the BOD of 6.66 mg/L.

When compared with the conditions in the upstream part of the two rivers (Bengawan Solo and Brantas), river pollution in the downstream is a manifestation of the pollution in the upstream since the water flows from the upstream to the downstream. The condition of the water quality in the downstream area of the two rivers is quite dangerous for the survival of the aquatic biota.

A BOD value above the quality standard indicates that the need for oxygen for biological processes is still relatively small, as there is a higher need for oxygen to support the chemical breakdown of organic matter. When the number of microorganisms is small, the biochemical breakdown process does not occur or the intensity of the biochemical breakdown is not significant. Under natural conditions, this effect is always caused by a number of toxic components (such as heavy metals) that adversely affect the enzyme activity of microorganisms (Franco-Duarte et al., 2019; Jeong & Choi, 2020). An indication of a high COD value indicates that the number of organic substances exceeds the maximum limit and is dangerous if directly released into the environment freely (Aniyikaiye et al., 2019).

The heavy metals present in the waters will one day fall and settle at the bottom of the waters forming sedimentation (Ouda et al., 2023). The aquatic biota foraging for food at the bottom of the waters will have a very large opportunity to be contaminated. According to Ayu et al. (2020), the presence of heavy metals in the water is very dangerous, especially to the life of the aquatic biota, which in turn affects indirectly to human health. This is related to the properties of heavy metals which are difficult to degrade, so that they accumulate in the aquatic environment and their presence naturally is difficult to remove.

Heavy metals naturally come from contaminated rocks and soil. Non-naturally, heavy metals come from the activities of residents who live around rivers such as industrial activities, agriculture, and household waste disposal (Herliwati et al., 2022; Oktarina et al., 2020). According to Hong et al. (2021), the effect of the rainy season can cause the decay of heavy metals both in water and in fish. The higher the intensity of rain, it can affect the rate of decay of heavy metals in the water. This can have an effect on the excessive accumulation of heavy metals in fish.

Mujair fish (*O. mossambicus*) is an invasive fish which is frequently found in both the Bengawan Solo river and the Brantas river. This is partly due to the short reproductive cycle and the survival of the fish which can handle stress (Nuryanto et al., 2022; Rahman et al., 2019). *O. mossambicus* eats various types of food available outside the cage and food which escapes from the cage. Based on the diagram of the average heavy metal content of Pb in each fish organ (Figure 1), it can be seen that the gills have the highest metal accumulation compared to the intestines and flesh. The accumulation of heavy metals in fish organs cannot be separated from the presence of heavy metals in the river water themselves (Hashim et al., 2014). Although Pb is a naturally occurring substance, its environmental concentration is significantly increased by anthropogenic sources such as Pb-based paints and leaded gasoline (Rahman et al., 2019; Hayati et al., 2017). In addition, Pb in water may come from pesticide containing lead, through precipitation, lead dust drop, road runoff, and municipal wastewater (Alengebawy et al., 2021; Levin et al., 2022). An excessive amount of Pb was found in the gills because gills are the first organs to receive substances entering the body when the fish breathe while some enter other organs through the blood (Kareem et al., 2022). The gill tissue can separate blood and water and is very susceptible to changes in variables such as heavy metals, pH, and temperature in the environment (Zaynab et al., 2022).

These variables affect the structural integrity of the gills. This is because the gills are an indicator that is directly exposed to water pollution because the filaments have a large surface area for direct contact so they are often contaminated in the water. The initial uptake of toxic substances by living things can be divided into three main processes including (1) from water through respiratory surfaces like gills, (2) from water into the body surface, and (3) from food, particles, or water ingested through the digestive system (Tanir, 2021; Yousif et al., 2021). In the research of Mahboob et al. (2016) stated that the amount of heavy metal accumulation from the largest to the smallest was gills > kidney > liver > flesh.

CONCLUSION

The condition of the water of Brantas and Bengawan Solo rivers is still supportive for the sustainability of fish life. The heavy metal content of Pb contained in *O. mossambicus* in each river is classified as very high and unfit for consumption. The level of bioaccumulation of Pb in organs from high to low was gills > flesh > intestines while the Pb content in each water is still relatively low.

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REFERENCES

Aida, S. N., Utomo, A. D., Anggraeni, D. P., Ditya, Y. C., Wulandari, T. N. M., Ali, M., … Suharman, I. (2022). Distribution of fish species in relation to water quality conditions in Bengawan Solo river , Central Java, Indonesia. *Plolish Journal of Environmental Studies, 31*(6), 5549-5561. doi: 10.15244/pjoes/152167.

Alengebawy, A., Abdelkhalek, S. T., Qureshi, S. R., & Wang, M.-Q. (2021). Plants : Ecological risks and human health implications. *Toxics, 42*(9), 1-33.

Aniyikaiye, T. E., Oluseyi, T., Odiyo, J. O., & Edokpayi, J. N. (2019). Physico-chemical analysis of wastewater discharge from selected paint industries in Lagos, Nigeria. *International Journal of Environmental Research and Public Health*, *19*(April), 1-17. doi: 10.3390/ijerph16071235.

Ayu, P., Setiyowati, I., Solekha, R., Sahara, S. B., & Hapsari, F. D. (2020). Analysis metallothionein of carp fish in the Brantas river, Indonesia. *EKSAKTA (Journal of Sciences and Data Analysis)*, *1*(2), 139-146. doi: 10.20885/EKSAKTA.vol1.iss.

Balali-mood, M., Naseri, K., Tahergorabi, Z., Khazdair, M. R., & Sadeghi, M. (2021). Toxic mechanisms of five heavy metals : Mercury, lead, chromium, cadmium, and arsenic. *Frontiers in Pharmacology*, *12*(April), 1-19. doi: 10.3389/fphar.2021.643972.

Bawuro, A. A., Voegborlo, R. B., & Adimado, A. A. (2018). Bioaccumulation of heavy metals in some tissues of fish in Lake Geriyo, Adamawa State, Nigeria. *Journal of Environmental and Public Health*, *2018*, 1-7. doi: 10.1155/2018/1854892.

Briffa, J., Sinagra, E., & Blundell, R. (2020). Heliyon heavy metal pollution in the environment and their toxicological effects on humans. *Heliyon*, *6*(August), 1-26. doi: 10.1016/j.heliyon.2020.e04691.

Franco-Duarte, R., Cernakova, L., Kadam, S., Kaushik, K. S., Salehi, B., Bevilacqua, A., … Rodrigues, C. F. (2019). Advances in chemical and biological methods to identify microorganisms — from past to present. *Microorganisms*, *130*(7), 1-32.

Hashim, R., Song, T. H., Muslim, N. Z. M., & Yen, T. P. (2014). Determination of heavy metal levels in fishes from the lower reach of the Kelantan river, Kelantan, Malaysia. *Tropical Life Sciencs Research*, *25*(2), 21-39.

Hayati, A., Yuliarini, N., Soegianto, A., Widyana, H., Rindaputri, I., Auliya, N., & Setiyowati, P. A. I. (2017). Metallothionein analysis and cell damage levels on the liver and gill of *Barbonymus gonionotus* in Brantas River, Indonesia. *Journal of Biological Researches*, *23*(1), 20-24. doi: 10.23869/bphjbr.23.1.20174.

Herliwati., Rahman, M., Hidayat, A. S., Amri, U., & Sumantri, I. (2022). The occurrences of heavy metals in water, sediment and wild shrimps caught from Barito estuary, South Kalimantan, Indonesia. *HAYATI (Journal of Bioscience)*, *29*(5), 643-647. doi: 10.4308/hjb.29.5.643-647.

Hong, H., Zhang, B., & Lu, H. (2021). Seasonal variation and ecological risk assessment of heavy metal in an estuarine mangrove wetland. *Water*, *2064*(13), 1-10.

Jaber, M. M. T., Al-Jumaa, Z. M., Nahi, H. H., Al-Hamdani, M. O., Al-Salh, M. A., & Al-Mayahi, B. (2021). Bioaccumulation of heavy metals and histopathological changes in muscles of common carp (*Cyprinus carpio* L .) in the Iraqi rivers. *Iraqi Journal of Veterinary Sciences*, *35*(2), 245-249. doi: 10.33899/ijvs.2020.126748.1368.

Jaishankar, M., Tseten, T., Anbalagan, N., Mathew, B. B., & Beeregowda, K. N. (2014). Toxicity, mechanism and health effects of some heavy metals. *Interdiciplinary Toxicology*, *7*(2), 60-72. doi: 10.2478/intox-2014-0009.

Jeong, S., & Choi, Y. J. (2020). Extremophilic microorganisms for the treatment of. *Molecules*, *25*(October), 1-16.

Kareem, S. I., Hussein, R. H., & Rasheed, R. O. (2022). Bioaccumulation of heavy metals in common carp fish (*Cyprinus carpio*) and its relationship with the protein content. *Iraqi Journal of Veterinary Sciences*, *36*(1), 173-178. doi: 10.33899/ijvs.2022.135834.2531.

Levin, R., Vieira, C. L. Z., Rosenbaum, M. H., Bischoff, K., Mordarski, D. C., & Brown, M. J. (2022). The urban lead (pb) burden in humans, animals and the natural environment. *Environmental Research*, *193*, 1-50. doi: 10.1016/j.envres.2020.110377.

Mahboob, S., Kausar, S., Jabeen, F., Sultana, S., Sultana, T., Al-Ghanim, K. A., … Ahmed, Z. (2016). Effect of heavy metals on liver , kidney , gills and muscles of *Cyprinus carpio* and *Wallago attu* inhabited in the Indus. *Brazilian Archives of Biology and Technology*, *59*(December), 1-10.

Manggara, A. B., & Prasongko, E. T. (2015). The analysis of lead (pb) in red nila fish (*Oreochromis* sp) in the floating net cages at in Brantas river Semampir Kediri. *Jurnal Wiyata*, *2*(2), 141-145.

Nuryanto, N., Afifah, D. N., Sulchan, M., Martosuyono, P., & Ihsani, K. (2022). Potential of nile tilapia (*Oreochromis niloticus*) as an alternative complementary food ingredient for stunting children. *Journal of Medical Science*, *10*, 1170-1177.

Oktarina, M., Yenny, P., Hartono, A., Anwar, S., & Kang, Y. (2020). Assessment of heavy metals pollution in sediment of Citarum River, Indonesia. *Journal of Natural Resources and Environmental Management*, *10*(4), 584-593. doi: 10.29224/jpsl.10.4.584-593.

Ouda, Y. W., Kadhim, K. F., & Amer, A. . (2023). Study of some toxic metals in parts from catfish (*Silurus triostegus*) in Shatt Al-Arab River. *Iraqi Journal of Veterinary Sciences*, *37*(2), 459-467. doi: 10.33899/ijvs.2022.135004.2435.

Rahman, U. R. A., Ismail, S. N. S., Abidin, E. Z., & Praveena, S. M. (2019). Heavy metals accumulation in gills and muscles of Mozambique tilapia (*Oreochromis mossambicus*) exposed to crude leachate. *Asian Journal of Agriculture and Biology*, *December*, 111-115.

Roestamy, M., & Ali, M. (2021). A review of the water resources management for the Brantas River basin : Challenges in the transition to an integrated water resources management. *Environment, Development and Sustainability*, *November*(1), 1-16. doi: 10.1007/s10668-02101933-9.

Sari, S. H. J., Iranawati, F., Chotimah, N., & Yunita, D. E. (2016). Bioconcentration of heavy metal cu in different tissues of milkfish [*Channos channos* (Forsskal , 1775)] in Ujung Pangkah, Gresik, East Java, Indonesia. *Aquatic Procedia*, *7*, 236-241. doi: 10.1016/j.aqpro.2016.07.033.

Tanir, O. Z. (2021). Deetermination of heavy metals in some tissues of four fish species from the Karasu river (Erzincan, Turkey) for public consumption. *International Journal of Oceanography and Hydrobiology*, *50*(2), 232-246. doi: 10.2478/oandhs-2021-0020.

Vareda, J. P., Valente, A. J. M., & Durães, L. (2019). Assessment of heavy metal pollution from anthropogenic activities and remediation strategies : A review. *Journal of Environmental Management*, *246*(December 2018), 101-118. doi: 10.1016/j.jenvman.2019.05.126.

Yousif, R. A., Choudhary, M. I., Ahmed, S., & Ahmed, Q. (2021). Review : Bioaccumulation of heavy metals in fish and other aquatic organisms from Karachi Coast, Pakistan. *Nusantara Bioscience*, *13*(1), 73-84. doi: 10.13057/nusbiosci/n130111.

Zaynab, M., Al-yahyai, R., Ameen, A., Sharif, Y., Ali, L., Fatima, M., … Li, S. (2022). Health and environmental effects of heavy metals. *Journal of King Saud University - Science*, *34*(1), 1-8. doi: 10.1016/j.jksus.2021.101653.