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IDENTIFICATION OF HEAVY METAL Cu AND Zn IN THE MEAT OF NILE TILAPIA (*Oreochromis niloticus*) AT IPAL BOJONGSOANG, BANDUNG REGENCY, WEST JAVA

Identifikasi Kandungan Logam Berat Cu dan Zn Pada Daging Ikan Nila (*Oreochromis niloticus*) di IPAL Bojongsoang, Kabupaten Bandung, Jawa Barat

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ABSTRACT

The Bojongsoang Wastewater Treatment Plant (IPAL) in Bojongsoang District, Bandung Regency, West Java, is a facility that processes wastewater from the city of Bandung. In the IPAL pond, there are Nile tilapia that live there and can serve as bioindicators of water quality. However, these fish are utilized by the surrounding community through fishing and netting for consumption and sale. This study aims to determine the safety level of Nile tilapia (Oreochromis niloticus) meat in the Bojongsoang IPAL based on the content of heavy metals Cu and Zn. The research was conducted from May to October 2024. The method used is a survey method with purposive sampling technique conducted at four pond sample collection locations. The accumulated heavy metal content in the Nile tilapia meat from the Bojongsoang IPAL Treatment Pond is as follows: Cu (0.1649 mg/kg, 0.1199 mg/kg, 0.1896 mg/kg, 0.1825 mg/kg) and Zn (2.5308 mg/kg, 1.9651 mg/kg, 2.3628 mg/kg, 2.5125 mg/kg). The levels of these heavy metals are still below the maximum limits set by Ditjen POM RI in 1989, indicating that the Nile tilapia meat collected from the Bojongsoang IPAL Treatment Pond is still safe for consumption based on its Cu and Zn heavy metal content.

Keywords: Cu, IPAL Bojongsoang, Nile Tilapia Meat, Zn

ABSTRAK

Instalasi Pengolahan Air Limbah (IPAL) Bojongsoang, Kecamatan Bojongsoang, Kabupaten Bandung, Jawa Barat, merupakan tempat pengolahan air limbah yang mengelola buangan domestik dari kota Bandung. Pada kolam IPAL tersebut terdapat ikan nila yang hidup dan dapat dijadikan bioindikator kualitas air, akan tetapi ikan tersebut dimanfaatkan oleh warga sekitar dengan cara dipancing dan dijaring untuk dikonsumsi maupun diperjual belikan. Penelitian ini bertujuan untuk menentukan tingkat keamanan daging ikan nila (*Oreochromis niloticus*) di IPAL Bojongsoang berdasarkan kandungan logam berat Cu dan Zn. Penelitian ini dilaksanakan dari bulan Mei - Oktober 2024. Metode yang digunakan dalam penelitian ini

adalah metode survei dengan teknik pengambilan sampel secara *purposive sampling* yang dilakukan di 4 kolam lokasi pengambilan sampel. Kandungan logam berat yang terakumulasi pada daging ikan nila di kolam *Treatmentt* IPAL Bojongsoang adalah Cu (0,1649 mg/kg, 0,1199 mg/kg, 0,1896 mg/kg, 0,1825 mg/kg), dan Zn (2,5308 mg/kg, 1,9651 mg/kg, 2,3628 mg/kg, 2,5125 mg/kg). Kandungan logam berat tersebut masih dibawah ambang batas maksimum yang telah ditetapkan oleh Ditjen POM RI 1989 dan daging ikan nila yang diambil dari Kolam *Treatment* IPAL Bojongsoang masih aman untuk dikonsumsi berdasarkan kandungan logam berat Cu dan Zn yang berada di dalamnya.

Kata Kunci: Cu, IPAL Bojongsoang, Daging Ikan Nila, Zn

INTRODUCTION

IPAL Bojongsoang, which operates under the Bandung City Regional Water Company (PDAM), plays a role in processing domestic waste that flows through a piping system. Water treatment at IPAL Bojongsoang uses a conventional system that combines aerobic and anaerobic biological processes, as well as physical-chemical and phytoremediation methods. Although effective, this method has the disadvantage of requiring a large area of land (Maulana & Marsono, 2021).

In the water treatment pond at IPAL Bojongsoang, especially the facultative and maturation ponds, fish such as tilapia and catfish were found to be living due to being carried away by floods. However, the most common fish found were tilapia. Although these fish have the potential to be used as indicators of water quality, local residents use them for consumption and for sale. This condition is a concern, considering that previous studies have found the presence of heavy metals such as Cr, Zn, Cu, and Ni at the outlet of IPAL Bojongsoang (Febrita & Roosmini, 2022), which indicates the possibility of heavy metal contamination in the treatment pond. Several hazardous wastes, such as used batteries, pans, and paint products, were also found in the inlet channel, which further strengthens the suspicion of heavy metals in the water.

Fish are aquatic biota that are often used as bioindicators of heavy metals in waters, because fish are included in the highest trophic level and a source of protein for humans. If fish contaminated with heavy metals are consumed by humans, the metals can accumulate in the human body and pose a health risk (Cahyani, 2016). Previous studies reported the accumulation of Cu and Zn metals in the liver of tilapia (Rachmadianti, 2013), Darmono's research (2001) stated that the amount of heavy metal accumulation in fish from the largest to the smallest in sequence is in the liver, kidneys, gills, to meat.

Although the Bojongsoang IPAL aims to reduce the levels of pollutants such as heavy metals so that processed water can be reused, Siregar's research (2004) showed that the content of heavy metals Cu and Zn was still detected in the waters. Cu and Zn are essential heavy metals needed by the body, although needed in small amounts, they can be toxic in high concentrations (Asria & Alhamid, 2020). Therefore, it is important to identify the heavy metal content in tilapia in the Bojongsoang IPAL processing pond to ensure its safety for consumption by the surrounding community. This study aims to analyze the content of heavy metals Cu and Zn in tilapia meat in the Bojongsoang IPAL pond and determine whether tilapia meat is safe for consumption based on the maximum limits that have been set.

METHODS

Time and Place

This research was conducted at the Bojongsoang IPAL, Jl. Cikoneng, Bojongsoang District, Bandung Regency, West Java, with a data collection period from April to July 2024. Fish samples were obtained from people who were fishing and netting. Measurement of metal

content in fish meat including Measurement of Heavy Metal Copper (Cu) and Heavy Metal Zinc (Zn) was carried out at the Central Laboratory of Padjadjaran University using Atomic Absorption Spectrophotometry (AAS).

Tools and Materials

The tools used during the study included Digital Scales, Cutting Boards, Knives, Plastic, Stationery, Cameras, Cool boxes, Labels, Choppers, Petri dishes, Hot Plates, Ovens, Tanneries, Whatman paper no. 40, 50 ml measuring flasks, Atomic Absorption Spectrophotometry. The materials used during the study were Tilapia weighing 22 - 28 g as many as 8 fish, Ice gel, concentrated HNO_3, 0.1N HNO_3, HCl.

Research Procedure

Fish sampling as research objects was carried out by purposive sampling as a sampling determination technique. The criteria that will be used in sampling are tilapia in facultative pond 2 sets A (F2A), maturation pond 2 sets A (M2A), maturation pond 1 set B (M1B), and maturation pond 2 sets B (M2B) caught by the community weighing 22 - 27 gr/tail as many as 8 fish in each pond with consideration of the minimum weight for sample testing and from the number of community catches. The sampling location can be seen in Figure 1.

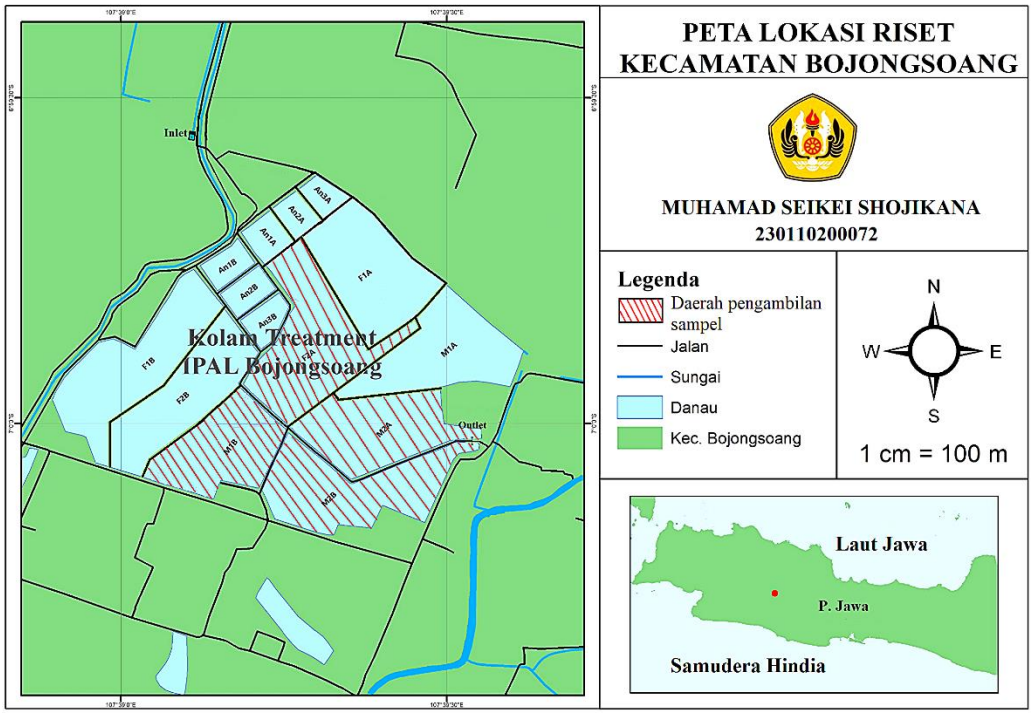

Figure 1. Sampling Location Map

Observation Parameters

The observed observation parameters and sample analysis methods are shown in Table 1.

Table 1. Parameters Measured and Measurement Methods

Parameter	Unit	Analysis Method	Observation Location
Chemical Parameters			
Heavy Metal Cu	mg/kg	Atomic Absorption Spectrophotometry (AAS)	Laboratory
Heavy Metal Zn	mg/kg	Atomic Absorption Spectrophotometry (AAS)	Laboratory

Data Analysis

Data analysis of observations of heavy metal content (Cu and Zn) in fish was carried out using comparative descriptive analysis. Data on heavy metal content in fish meat will be compared with the quality standards of the Directorate General of POM RI Number 03725/B/SK/VII/89 of 1989 are shown in Table 2.

Table 2. Maximum Limit of Metal Contamination in Food according to the Directorate General of POM RI Number 03725/B/SK/VII/89

Commodity	Copper (Cu) mg/kg	Zinc (Zn) mg/kg
Fish and processed fish products	20	100

RESULT

Heavy Metal Content of Copper (Cu) in Fish Meat

The Copper (Cu) content in tilapia fish meat at the sampling pond location in pond 1 showed 0.1649 mg/kg, pond 2 0.1199 mg/kg, pond 3 0.1896 mg/kg, and pond 4 0.1825 mg/kg. The highest content of Copper (Cu) in tilapia fish meat was in the sample of pond 3, while the lowest was in the sample of pond 2. The results of the analysis of the heavy metal content of Copper (Cu) in tilapia fish meat at the sampling pond location can be seen in Table 3.

Table 3. Cu Metal Content in Tilapia Fish Meat

Measured Parameters	Unit	Cu Metal Content in Tilapia Fish Meat				Quality Standards (mg/kg)
		F2A	M2A	M1B	M2B	
Cu	mg/kg	0.1649	0.1199	0.1896	0.1825	20

Heavy Metal Zinc (Zn) Content in Fish Meat

The Zinc (Zn) content in tilapia fish meat at the sampling pond location in pond 1 showed 2.5308 mg/kg, pond 2 1.9651 mg/kg, pond 3 2.3628 mg/kg, and pond 4 2.5125 mg/kg. The highest heavy metal Zinc (Zn) content in tilapia fish meat was in the sample of pond 1, while the lowest was in the sample of pond 2. The results of the analysis of the heavy metal Zinc (Zn) content in tilapia fish meat at the sampling pond location can be seen in Table 4.

Table 4. Zn Metal Content in Tilapia Fish Meat

Measured Parameters	Unit	Zn Metal Content in Tilapia Fish Meat				Quality Standards (mg/kg)
		F2A	M2A	M1B	M2B	
Zn	mg/kg	2.5308	1.9651	2.3628	2.5125	100

Safety Level of Fish Meat for Consumption

The safety level of fish meat for consumption plays an important role in maintaining public health. One way to measure the safety of meat for consumption is the Acceptable Daily Intake (ADI), which is defined as the maximum amount of a chemical that can be consumed daily over a lifetime without significant health risks, and is based on the highest intake that does not cause observable side effects (Kurniawan, 2019). ADI can be formulated as follows (EUFIC, 2021):

$$\text{ADI (µg/kg BW/day)} = \frac{\text{Heavy metal concentration in fish } \left(\frac{\text{mg}}{\text{kg}}\right) \text{ x amount of fish consumption } \left(\frac{\text{mg}}{\text{day}}\right)}{\text{Body Weight (mg)}}$$

Assumption:
Body weight (BW) 60 kg = 60,000,000 mg
Fish consumption 150 g/day = 150,000 mg/day

The results of the calculation of the safety level of consuming tilapia meat at the Bojongsoang IPAL can be seen in table 5.

Table 5. Results of the Calculation of Acceptable Daily Intake (ADI) of Cu and Zn Metals

Metal Type	Unit	Sampling Location				Quality Standards (µg/kg BW/day)
		F2A	M2A	M1B	M2B	
Cu	mg/kg BW/day	0.0004	0.0003	0.0005	0.0005	0.5
Zn	mg/kg BW/day	0.0063	0.0049	0.0059	0.0062	1

DISCUSSION

Different heavy metal content in fish meat can be caused by the accumulation of heavy metals in the organism's body, depending on the heavy metal content in the water (Fajri, 2001). Another factor that affects the difference in heavy metal content in tilapia fish meat in each pond is caused by ponds 1 and 2 which are in set A, and ponds 3 and 4 which are in set B. Based on the results of interviews with Bapak Heri as the manager of the Bojongsoang IPAL, he explained that the set A pond is more often used to manage wastewater compared to the set B pond. Maintenance in the Set A pond tends to get more frequent maintenance such as dredging sediment and controlling the growth of water hyacinth compared to the Set B pond because the manager at the Bojongsoang IPAL has few employees, so the Set A pond gets more frequent maintenance such as dredging sediment and controlling the growth of water hyacinth compared to the Set B pond. There are 8 employees who specifically manage the treatment pond and it takes 1 month to carry out maintenance on the 2 anaerobic set A ponds alone, such as dredging sediment and controlling the growth of water hyacinth so that it does not grow back in the treatment pond. This resulted in the Set B pond rarely being dredged for sediment and the water hyacinth plants in the pond growing uncontrollably. The high Zn heavy metal in tilapia fish meat is thought to be due to the nature of the Zn heavy metal which is easily dissolved in water as a free divalent ion such as Zn^{2+} which has a high affinity for sediment so that it is easily absorbed by the sediment (Rumhayati, 2019).

The results of the study on the content of Copper (Cu) heavy metal in tilapia fish meat based on the maximum threshold for metal contamination in food according to the Directorate General of POM RI Number 03725/B/SK/VII/89, the heavy metal detected in tilapia fish meat is still below the maximum limit set, which is 20 mg/kg. The content of Zn heavy metal detected in tilapia fish meat is still below the maximum limit set by the Directorate General of POM RI Number 03725/B/SK/VII/89, concerning the limit for metal contamination in food of 100 mg/kg.

The calculation results of Acceptable Daily Intake (ADI) show that the consumption level of tilapia fish meat of 150,000 mg/day (150 g/day) which accumulates heavy metals Cu and Zn for adults weighing 60,000,000 mg (60 kg) is still below the Acceptable daily intake (ADI) set by WHO in 1982 of 0.5 mg/kg body weight per day for heavy metal Cu and 1 mg/kg body weight per day for heavy metal Zn. The heavy metal content in tilapia fish meat detected in this study is still safe for human consumption. Considering that the heavy metal content in tilapia fish meat is still below the threshold, the tilapia fish meat in the Bojongsoang IPAL pond meets health requirements and can be consumed by humans based on the content of heavy metals copper (Cu) and zinc (Zn) detected.

CONCLUSION

The content of heavy metals accumulated in tilapia fish meat in the Bojongsoang IPAL Treatment pond from the largest to the smallest in sequence are Zn heavy metal (2.5308 mg/kg)

in the Facultative pond 2 set A and Cu heavy metal (0.1896 mg/kg) in the Maturation pond 1 set B. The content of these heavy metals is still below the maximum threshold set by the Directorate General of POM RI (1989). Tilapia fish meat taken from the Bojongsoang IPAL Treatment Pond is still safe for human consumption based on the content of Cu and Zn heavy metals.

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REFERENCES

Afrianto, I. E., & Liviawaty, I. E. (1992). *Pengendalian Hama & Penyakit Ikan*. Yogyakarta; Kanisius.

Amiruddin, A., & Lubis, F. A. (2018). Analisa Pengujian Lelah Material Tembaga Dengan Menggunakan Rotary Bending Fatigue Machine. *Mekanik*, *4*(2), 329180.

Angraini, S. (2010). Kandungan Logam Berat Cd, Cu, dan Zn Pada Daging Ikan Nila Dalam Karamba Jaring Apung (KJA) di Blok Jangari Waduk Cirata. *Skripsi*. Jawa Barat: FPIK Universitas Padjadjaran.

Arief, L. M. (2016). *Pengolahan Limbah Industri: Dasar-dasar Pengetahuan dan Aplikasi di Tempat Kerja*. Yogyakarta: Penerbit Andi.

Asria, M., & Alhamid, F. (2020). Analisis Kandungan Logam Berat Cu dan Zn dalam Air Limbah Industri. *REACTOR: Journal of Research on Chemistry and Engineering*, *1*(2), 29-31.

Badan Standarisasi Nasional. (1998). *Cara Uji Cemaran logam Dalam Makanan*. Jakarta.

Bost, M., Houdart, S., Oberli, M., Kalonji, E., Huneau, J. F., & Margaritis, I. (2016). Dietary Copper and Human Health: Current Evidence and Unresolved Issues. *Journal of Trace Elements in Medicine and Biology*, *35*, 107-115.

Cahyani, N., Batu, D. T. F. L., & Sulistiono, S. (2016). Kandungan Logam Berat Pb, Hg, Cd, dan Cu Pada Daging Ikan Rejung (*Sillago sihama*) di Estuari Sungai Donan, Cilacap, Jawa Tengah. *Jurnal Pengolahan Hasil Perikanan Indonesia*, *19*(3), 267-276.

Darmono. (1995). *Logam Dalam Sistem Biologi Makhluk Hidup*. Depok: Penerbit Universitas Indonesia.

Darmono, L. H., & Hidup, L. (2001). Pencemaran hubungannya Dengan Toksikologi Senyawa Logam. *Penerbit Universitas Indonesia, Jakarta*.

Direktorat Jendral Pengawasan Obat dan Makanan. (1989). *Batas Maksimum Cemaran Logam Dalam Makanan*. Jakarta.

Effendi, H. (2003). *Telaah Kualitas Air Bagi Pengelolaan Sumberdaya Dan Lingkungan Perairan*. Jakarta: PT Kanisius.

Ekaputri, S. A. (2023). Kelayakan Kualitas Air Hasil Olahan Limbah Cair Domestik di IPAL Bojongsoang, Kabupaten Bandung untuk Budidaya Ikan. *Skripsi*. Jawa Barat: FPIK Universitas Padjadjaran.

Europan Food Information Council. (2021). What Is an Acceptable Daily Intake (ADI). https://www.eufic.org/en/understanding-science/article/qas-on-acceptable-daily-intakes-adis

Fajri, N. E. (2001). Analisis kandungan logam berat Hg, Cd dan Pb dalam air laut, sedimen dan tiram *(Crassostrea cucullata)* di Perairan Pesisir Kecamatan Pedes, Kabupaten Karawang, Jawa Barat: Pasca Sarjana IPB.

Febrita, J., & Roosmini, D. (2022). Analisis beban pencemar logam berat industri terhadap

kualitas sungai Citarum Hulu. *Jurnal Teknik Sipil Dan Lingkungan*, *7*(1), 77-88.

Hardani, P. T., Pramushinta, I. A. K., & Purbosari, I. (2022). Penyuluhan Pemanfaatan Belimbing Wuluh (*Oreochromis mossambicus* dan Asam Sitrat Untuk Mengurangi Cemaran Logam Berat Pada Ikan. *Pancasona: Pengabdian dalam Cakupan Ilmu Sosial dan Humaniora*, *1*(1), 23-28.

Ika, L. P. (2008). Penetapan kadar Fe dan Zn di dalam tempe yang di pasar kartasura dengan menggunakan metode pengaktifan neutron. *Skripsi. Universitas Muhammadiyah Surakarta*.

Irianti, T. T., Kuswandi, K., Nuranto, S., & Budiyatni, A. (2017). *Logam Berat dan Kesehatan. Yogyakarta: CV Grafika Indah.*

Kadang, L. (2005). *Analisis Status Pencemaran Logam Berat Pb, Cd Dan Cu Di Perairan Teluk Kupang Provinsi Nusa Tenggara Timur.* (Doctoral dissertation, Thesis S2. Institut Pertanian Bogor).

Khaira, K. (2016). Analisis kadar Tembaga (Cu) dan Seng (Zn) dalam air minum isi ulang kemasan galon di kecamatan Lima Kaum kabupaten Tanah Datar. *Sainstek: Jurnal Sains dan Teknologi*, *6*(2), 116-123.

Kordi, K., Ghufron, M. H. (1997). *Budidaya Air Payau*. Semarang: Dahara Prize.

Kurniawan, A. (2019). *Dasar-Dasar Analisis Kualitas Lingkungan*. Wineka Media.

Maddusa, S. S., Paputungan, M. G., Syarifuddin, A. R., Maambuat, J., & Alla, G. (2017). Kandungan logam berat timbal (Pb), merkuri (Hg), zink (Zn) dan arsen (As) pada ikan dan air Sungai Tondano, Sulawesi Utara. *Al-Sihah: The Public Health Science Journal*.

Mara, D. (2013). *Domestic Wastewater Treatment in Developing Countries*. Britania Raya: Routledge.

Margareta, S. N. (2019). Analisis kandungan logam berat (Pb, Cu, Cd, dan Hg) pada air minum isi ulang di Kota Malang berbasis spektroskopi serapan atom menggunakan metode PCA. *Dissertation*. Malang: Universitas Islam Negeri Maulana Malik Ibrahim.

Maulana, M. R., & Marsono, B. D. (2021). Penerapan Teknologi Membran untuk Mengolah Limbah Cair Industri Tahu (Studi Kasus: UKM Sari Bumi, Kabupaten Sumedang). *Jurnal Teknik ITS*, *10*(2), F54-F60.

Menteri Lingkungan Hidup dan Kehutanan Republik Indonesia. (2016). *Baku Mutu Air Limbah Domestik*. Jakarta.

Mudjiman, A. (1990). *Budidaya Ikan Nila*. Yogyakarta: CV Yasaguna.

Muhammadong, M., & Rahmawati, R. (2022). Analisis Kadar Serum Glutamic Oxaloacetic Transaminase (SGOT) dan Serum Glutmic Pyruvic Transaminase (SGPT) pada Petugas Berisiko Tinggi. *Jurnal Keperawatan Profesional (KEPO)*, *3*(2), 131-137.

Mutiara, A. A. (2013). Akumulasi Timbal (Pb) Dan Kadmium (Cd) Serta Kerusakan Pada Insang, Hati Dan Daging Ikan Patin (*Pangasius* Sp.) Di Waduk Saguling. Jurnal Perikanan dan Kelautan, 4: 1-10.

National Institutes of Health. (2022). *Copper Fact Sheet for Health Profesionals*. Amerika Serikat.

National Institutes of Health. (2022). *Zinc Fact Sheet for Health Profesionals*. Amerika Serikat.

Olivia, F., Alam, S., & Hadibroto, I. (2006). *Seluk Beluk Food Suplement*. PT. Gramedia Pustaka Utama.

Palar, H. (1994). *Pencemaran dan Toksikologi Logam Berat*. Rineka Cipta.

Pangesti, I., Nugroho, Y. E., Faizal, I. A., Utami, T. F. Y., & Priyanto, A. (2020). Pemanfaatan Belimbing Wuluh (*Averrhoa bilimbi* L.) Untuk Menurunkan Kadar Logam Cu Pada Ikan Belanak (*Chelon subviridis*). *Pharmaqueous: Jurnal Ilmiah Kefarmasian*, *2*(2), 109-115.

Perusahaan Daerah Air Minum. (2023). Air Limbah. Bandung.

Plum, L. M., Rink, L., & Haase, H. (2010). The essential toxin: impact of zinc on human health. *International journal of environmental research and public health*, *7*(4), 1342-

1365.
Pramushinta, I. A. K. (2020). Penurunan Kandungan Logam Berat Zn pada Ikan Mujair (Oreochromis mossambicus) dengan Metode Maserasi Belimbing Wuluh (Averrhoa Bilimbi). *FARMASIS: Jurnal Sains Farmasi*, *1*(1), 33-36.
Priyadi, S., Darmadji, P., Santoso, U., & Hastuti, P. (2013). Khelasi Plumbum (Pb) Dan Cadmium (Cd) Menggunakan Asam Sitrat Pada Biji Kedelai. *Jurnal Universitas Gadjah Mada*, 33(4).
Rachmadianti, M. M. (2013). Analisis Kandungan Logam Berat Seng (Zn) dan Tembaga (Cu) pada Ikan Nila dan Perairan Waduk Cirata Purwakarta, Jawa Barat: Insitut Pertanian Bogor.
Rahmayanti, D. P. (2018). Analisis Risiko Logam Berat Seng (Zn) Dalam Total Suspended Particulate (TSP) Terhadap Kesehatan Manusia di Terminal Bus Giwangan dan Jombor, DI Yogyakarta. Yogyakarta: Univeritas Islam Indonesia.
Riffat, R. (2012). *Fundamentals of Wastewater Treatment and Engineering*. Florida: CRC Press.
Rukman, R. (1997). *Ikan Nila Budidaya dan Prospek Agribisnis*. Yogyakarta: Kanisius.
Rumhayati, B. (2019). *Sedimen Perairan (Kajian Kimiawi, Analisis, dan Peran)*. Malang: UB Press.
Saanin, H. (1984). *Taksonomi dan Kunci Identifikasi Ikan*. Jakarta: Bina Cipta.
Setyawati, E. (2000). Kandungan logam berat Plumbum (Pb) pada air limbah domestik dan daging Ikan Nila (*Oreochromis niloticus* Trewayas) di Instalasi Pengolahan air Limbah (IPAL) Bantul Yogyakarta. *Dissertation*, Semarang: FMIPA UNDIP.
Shindu, S. F. (2005). Kandungan Logam Berat Cu, Zn, dan Pb dalam Air, Ikan Nila (*Oreochromis niloticus*) dan Ikan Mas (*Cyprinus carpio*) dalam Keramba Jaring Apung, Waduk Saguling. *Dissertation*. Bogor: Bogor Agricultural University.
Siregar, S. (2004). Studi Sistem Operasi dan Pemeliharaan (O&P) Instalasi Pengolahan Air Limbah (IPAL) (Studi Kasus IPAL Bojongsoang Kota Bandung). *Tesis*. Semarang (ID): Universitas Diponegoro).
Sugiantari, I. A. P., Sukmaningsih, A. A. S. A., & Wijana, I. M. S. (2022). Kajian struktur histologi hati, insang dan lambung Ikan Nila (*Oreochromis niloticus*) di Danau Batur, Bangli. *Buletin Anatomi dan Fisiologi*, *7*(1), 51-59.
Sugiarto. (1988). *Teknik Pembenihan Ikan Mujair dan Nila*. Surabaya: CV. Simplex.
Sugiyono, P. D. (2019). Metode Penelitian Pendidikan (Kuantitatif, Kualitatif, Kombinasi, R&D Dan Penelitian Pendidikan). *Metode Penelitian Pendidikan*, *67*.
Supriyanto, C., & Samin, Z. K. (2007). Analisis cemaran logam berat Pb, Cu, dan Cd pada Ikan air tawar dengan metode spektrometri NyalaSerapan atom (SSA). In *Proceedings of the Jurnal Seminar Nasional III*. 147-152.
Susanti, D. R., Sari, I. P., Ulfah, R., & Nadia, S. N. (2017). *Pemeriksaan Air Limbah Secara Laboratorium di Bagian Pengolahan Air Limbah*. Universitas Pendidikan Indonesia.
Triadiati, R. I., Suprihadi, A., & Lunggani, A. T. (1997). Studi Pendahuluan Mengenai Pemanfaatan Mikroba Sungai untuk Menanggulangi Pencemaran Logam Berat di Perairan. Laporan penelitian UNDIP, Semarang.
Todd, L. M., Godber, I. M., & Gunn, I. R. (2004). Iatrogenic copper deficiency causing anaemia and neutropenia. *Annals of clinical biochemistry*, *41*(5), 414-416.
Wajong, R. S., & Rotinsulu, W. C. (2022). Pengaruh Penyerapan Eceng Gondok (*Eichornia crassipes*) Dan Apu Apu (*Pistia stratiotes*) Terhadap Konsentrasi Cu Dan Zn Pada Air Limbah Pertambangan PT J Resources Bolaang Mongondow. *AGRI-SOSIOEKONOMI*, *18*(3), 765-774.
Widowati, W., Sastiono, A., dan Jusuf, R. (2008). *Efek Toksik Logam*. Yogyakarta: Andi.
Wigati, S. A., Kilawati, Y., & Pi, S. (2021). Status Histologi Insang Ikan Wader (Rasbora

Argyrotaenia) Di Sungai Metro Kepanjen, Malang Yang Mengandung Logam Berat Kromium (Cr). *Dissertation*. Malang: Universitas Brawijaya.

World Health Organization. (1982). *Evaluation of Certain Food Additives and Contaminants*. Geneva.

Widowati, W., Sastiono, A. & Jusuf, R. (2008). *Efek Toksik Logam*. Yogyakarta: Andi.