International Journal of Research in Engineering, Science and Management
Volume 7, Issue 12, December 2024
https://www.ijresm.com | ISSN (Online): 2581-5792

Implementation of a Web-based System for Monitoring Water Quality and Fish Health Indicators

Zahrotul Istiqomah[1*], Christin Risbandini[2], Afendi Adi Hermawan[3], Slamet[4], Hamzah Fansuri[5], Endry Nugroho Prasetyo[6]

[1,4,5]*Department of Chemistry, Faculty of Science and Data Analytics, Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia*

[2,3,6]*Department of Biology, Faculty of Science and Data Analytics, Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia*

***Abstract*: Water quality and fish health are two important interrelated aspects of the pond ecosystem, in areas adjacent to wastewater treatment sources. In this study, the observed water quality parameters were pH, temperature, and electricity conductivity (EC) measured periodically. Meanwhile, fish health was assessed based on visual indicators of fish morphometry and histology. Data obtained from sensors and observations were collected and processed through a web-based system that can be accessed real-time by users. Water quality observations of the Chemistry and Physics Departments ponds were carried out for 1 month, with data collection in 1 week carried out 3 times. While observations for fish health were made within a span of 1 month. Data observation parameters of temperature, pH and EC for pond water of the Department of Chemistry and Physics, the average temperature is 30 ⁰C, the pH in the chemistry pond has an acidic pH and the pH in the Physics pond has an alkaline pH. While the average EC value in the Chemistry and Physics ponds were 2.5273 and 2.5218 µS/cm respectively. The results of fish histology slide, including gills, liver and kidneys, showed some damage to these organs in both ponds in the Department of Physics and Chemistry, characterized by organ deformities compared to the control pond. The tissue damage in those organs might be due to the content of heavy metal or pollutants above the normal standard from the Wastewater Treatment Plant - Faculty of Science and Data Analysis, Institut Teknologi Sepuluh Nopember (IPAL FSAD).**

***Keywords*: aquatic ecosystem, fish histology, water quality, web-based.**

1. Introduction

Wastewater Treatment Plant (WWTP) is one of the commonly used solutions to process waste before it is released into the environment. The current WWTP is located between the Chemistry and Physics Departments of the Faculty of Science and Data Analytics (FSAD). Although the WWTP aims to reduce the negative impact of effluents, some potential environmental issues could still arise, especially if the WWTP is not functioning properly or the effluents exceed its capacity. One important aspect to consider is the impact of the WWTP effluent on the water quality in the surrounding environment, especially if there are fish in the pond. The water quality and health of the fish in the ponds around the WWTP are important indicators of the condition of the aquatic environment. If the fish show symptoms of illness or stress, this could be a sign of water quality problems or pollution.

Currently, the commonly used monitoring methods for water and fish quality measurements are direct observation and laboratory testing, however, this approach is time-consuming, difficult, and must be carried out continuously, hence the need to develop more efficient monitoring methods that can be accessed in real-time. In today's digital era, information and communication technology offers great potential to improve environmental monitoring by utilizing a web-based system, information about fish health can be accessed directly from the pond. This is very helpful for monitoring fish health and water quality more efficiently and responding to changing conditions quickly.

Water quality can be monitored using sensors as supporting components during monitoring that are connected to the internet so that they can be read in real time. Therefore, this research aims to develop a web-based system to monitor fish health indicators and water quality in ponds around WWTPs that have never been studied and done before. By PERMENKES RI, the parameters studied include temperature, acidity (pH), electricity conductivity (EC) related to the amount of dissolved ion content in pond water, and the web as an interface. Through this approach, it is expected that monitoring of fish health and water quality can be carried out more efficiently and effectively, thus assisting in the sustainable management of the aquatic environment in the FSAD environment.

2. Material and Methods

A. Materials

The equipment used in this research are a set of glassware, pvc pipe, net, pH meter sensor, temperature sensor, electric conductivity sensor, water pumps, water hose, aquarium, a wooden boat, a surgical board, a dissecting set, batere, remote control, rotary microtome, microtome blade, brushes, object glass, staining jars, cover glass, water bath, oven, hot plate,

*Corresponding author: istiqomahzahrotul@gmail.com

microscope and optilab. While the materials used are buffer solution, formalin solution, tilapia fishes, Haematoxylin-Eosin staining chemicals, alcohol series solutions, paraffin, xylol solution, entellan, glycerine-albumin solution, aquadest, and standard solutions.

B. Methods

1) Tilapia Rearing, Sampling, and Making Histological Preparate

A number of tilapias were first conditioned in the control aquarium for one week before being moved to the physics department pond and chemistry department pond. The fish sampled were uniform in weight and length. After 1 week, a number of fish were transferred to the two ponds with a total of 15 fish each, and left for one month, and also for normal control fishes still at the aquarium. In both ponds, the fishes used as the object of research were placed in a box made of PVC pipes covered, dimensions (60x60x100) cm^3 substitute of aquariums, which are covered with nets and labelled to avoid misidentify. The size of the fishes refers to the standard size for tilapia cultivation, and each habitat contains 10 - 15 fishes.

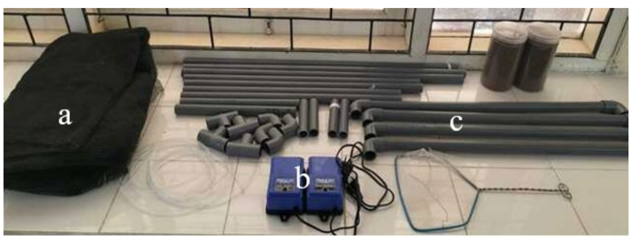

Fig. 1. Fishes rearing
(a. Net; b. Water pump; c. PVC pipe)

After one month, the fishes were taken to make histology preparate of the gill, kidney and liver organs using the paraffin method. Fish were placed on the surgical table, cut lengthwise and each 2 cm of gill, kidney and liver organs were taken and immersed in 0.89% physiological saline solution then fixed in the buffer formalin. Each organ was cut into 0.3 cm pieces and soaked with 70% alcohol.

To make histology preparate, there are some procedures that must be carried out. First, dehydration process was carried out by entering the samples into alcohol series solution, then the clearing process by inserting the samples into xylol series solutions. Then the paraffin infiltration process was carried out in the oven, then the embedding is taken place by making paraffin blocks, which is the samples were embedded into paraffin using cassette until harden. After hardening, the sample was cut transversely and longitudinally using a microtome with a thickness of 6 µm, the results of the incision were attached to a cover glass that had been given glycerine-albumin Furthermore, the staining process was carried out using Haematoxylin-Eosin. The last process is mounting, which is closing the cover glass that is glued with entellan [a].

Then the preparates were observed under a microscope and after the tissue is clear, microscopic photos are made using optilab.

2) Water Quality Measurement

Water monitoring devices are essential tools used to assess and manage water quality in various environments, including natural water bodies, municipal water supplies, industrial applications, also wastewater treatment plant. These devices can measure a range of parameters to ensure that water meets safety and quality standards [b]. The wooden board is modified with several sensors to measure the water quality in the pond around the chemical department wastewater treatment plant, then connected to the web and IoT using the ESP32microcontroller, so that it can generate data in real time. There are sensors that installed in the wooden board, such as temperature sensor, electric conductivity sensor, and pH sensor.

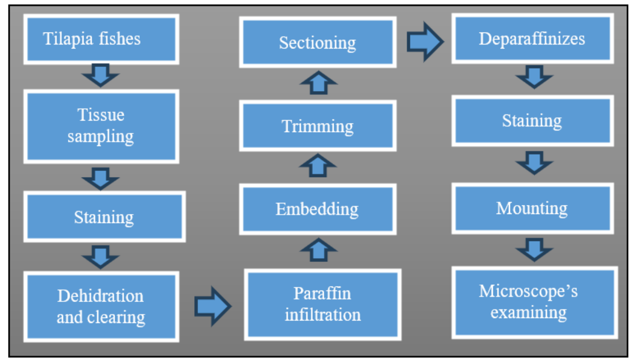

Fig. 2. Fishes histological preparator's procedures

The Power of Hydrogen (pH) sensor is a sensor used to measure a degree of acidity in a liquid. This tool has a range of 0-14, where for a neutral pH value has a value of 6.5 to 7.5 when less than 6.5 the liquid is said to be acidic and or more than 7.5 then the liquid is worth alkaline [c]. Temperature sensors are essential for monitoring water quality because temperature influences chemical and biological processes in aquatic environments. They help detect changes in water temperature, which can indicate potential issues such as thermal pollution or the mixing of different water layers. Electric conductivity sensors measure the ability of water to conduct electricity, which correlates with the concentration of dissolved ions (salts) in the water. High conductivity levels can indicate pollution or high salinity levels [d].

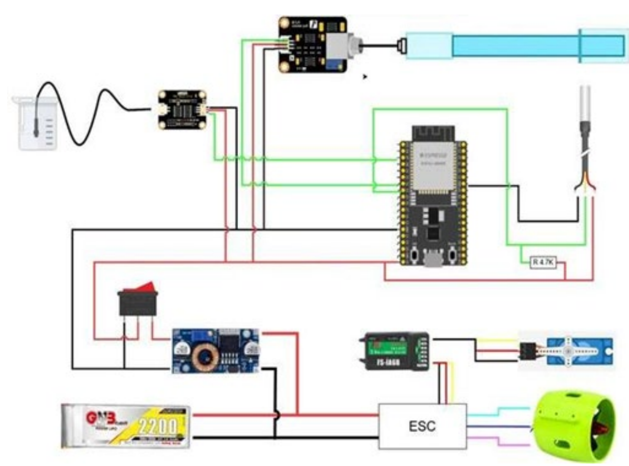

Fig. 3. Water monitoring device's diagram

The figure 3 above the communication in the wooden boat.

The three sensors are connected to a ESP32 microcontroller, that has high performance capabilities with a compact form and wi-fi connectivity. The wi-fi feature will be used to send the data read by the microcontroller to the cloud real time database so that the data can be accessed in real-time from anywhere. To supply power to the microcontroller, a Lithium Polymer 4S battery is used which is converted with a step-down buck converter so that the voltage received by the ESP32 can be stabilized at 5 Volts. This power is also later used by each sensor. The 4S battery is used because it is suitable for supplying power to the electric motor used to move the wooden boat so that the water monitoring point can be reached easily. Power from the battery is channelled first to the ESC (Electronic Speed Controller) which functions as a motor speed regulator by receiving a signal from the remote controller receiver. The wooden boat use a servo to move the rudder which functions to change the direction while operating in the water.

Figure 4 of the system design below shows the inputs contained in the system are the EC sensor, pH sensor, and tempera sensor, then connected to the microcontroller to process data from the three sensors used. Then the output of the system will be displayed on the website through a cloud system using a laptop or mobile phone that has been connected to the internet.

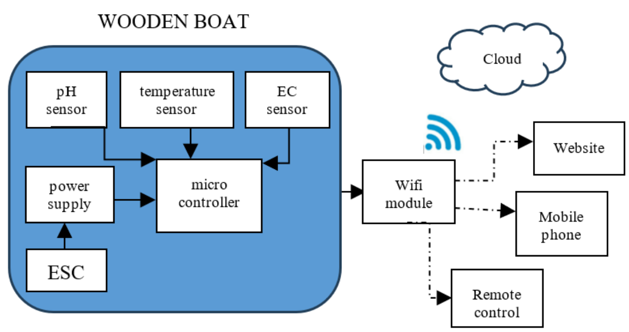

Fig. 4. Water monitoring device's design

3) *Test Procedure*

The procedure of the Water Monitoring System was conducted by placing it into ponds. There are several steps to use and connect it to the web system. The following is a flowchart test procedure:

3. Results and Discussion

The picture below is, the result of designing the water monitoring device using a wooden boat device equipped with a microcontroller, temperature sensor, pH sensor, and EDC sensor.

Web Display Results using Blynk IoT Software. The web displays a value or result from the measurement of the sensors used, temperature sensor, pH sensor, and EDC sensor. This web is still shortcomings where the website cannot save data that has previously appeared, so the data will repeat back to the beginning and cannot see data that has previously appeared first.

A. *Wastewater Treatment Plant (WWTP) Observations*

The measurement of water quality indicators in ponds around the ITS Faculty of Science and Data Analytics Wastewater Treatment Plant (FSAD WWTP) was carried out in an integrated equipment with a web-based platform. This system allows real-time monitoring of pond water quality. The main parameters measured include pH, temperature, and electrical conductivity (EC), that are closely related to the balance of the pond ecosystem and as an indicator of water quality. This observation uses sensors installed in the wooden boat with remote control integrated with the web.

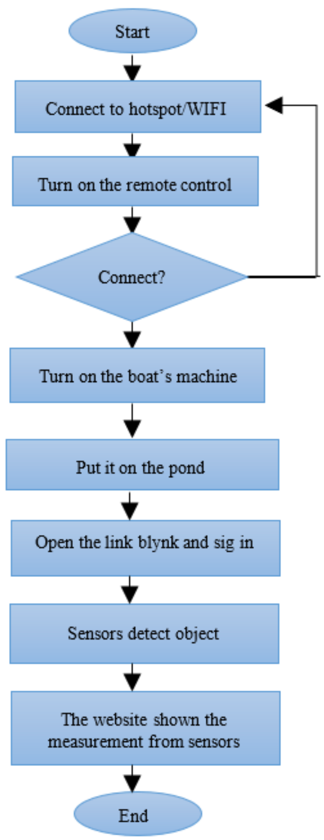

Fig. 5. Water monitoring device's flowchart procedures

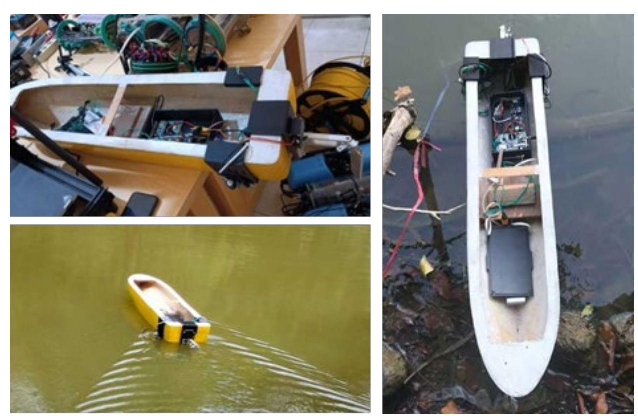

Fig. 6. Water monitoring's wooden boat

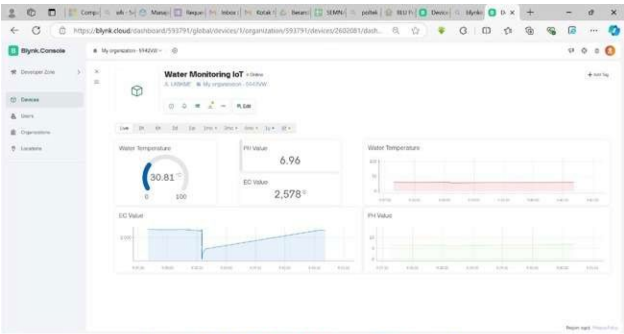

Fig. 7. Web display

Table 1
Observation data in chemical's pond and physics' pond

No.	Chemical's Pond			Physics' Pond		
	Temp.	pH	EC	Temp.	pH	EC
1	31,88	6,8	2,484	31,44	8,11	2,464
2	31,81	6,81	2,466	31,56	8,22	2,474
3	31,56	6,69	2,452	31,56	8,24	2,476
4	31,94	6,69	2,468	31,56	8,28	2,474
5	32,06	6,74	2,494	31,44	8,32	2,464
6	32,12	6,72	2,386	31,31	8,07	2,458
7	32,88	6,33	2,598	31,12	8,01	2,454
8	32,81	6,29	2,588	32,44	8,2	2,540
9	32,88	6,31	2,606	32,38	7,46	2,542
10	34,88	7,07	2,628	35,31	8,02	2,632
11	30,81	6,96	2,578	35,32	8,01	2,630
12	30,88	6,99	2,58	31,25	7,42	2,654

From data's above shows that the pH, temperature and EC can be explained as follows:

1) pH's Water

The measurement results show that the pond in front of the Chemistry Department has an acidic pH, while the pond in front of the Physics Department has an alkaline pH. This difference in pH has the potential to affect the health conditions of the fish in each pond. The acidic pH in the Chemistry Pond may be caused by the flow of wastewater or the content of organic substances undergoing decomposition, which usually increases the acidity of the water. In contrast, the alkaline pH in the Physics Pond may be caused by natural chemical processes or exposure to alkaline compounds that may be present in the environment surrounding the FSAD WWTP. These non-neutral pH conditions can impact fish stress levels, affect respiration, as well as ionic balance in the fish body.

2) Temperature's Water

The average temperature measured in both ponds was 30°C. This temperature is within the tolerance range of most fish species, although too high a temperature can increase the oxygen demand of the fish while reducing the dissolved oxygen levels in the water. This is important to consider in pond management, especially around sewage treatment areas that have the potential to increase the thermal load on aquatic ecosystems.

3) Electrical Conductivity (EC)'s Water

The average EC values in the Chemical and Physical ponds were 2.5273 and 2.5218 µS/cm, respectively. These values indicate a high content of dissolved ions in the pond water, which may come from sewage or other solutes. High conductivity can have an impact on fish physiological stress, as it indicates high concentrations of potentially toxic minerals or solutes. Under optimal conditions, EC values should be within a range that does not cause discomfort to fish, so adjustments need to be made to the ponds if these EC levels continue to increase.

Research shows that the difference in water quality in the Chemistry's Department Pond and the Physics' Department Pond have a significant impact on the ecosystem conditions of each pond. Fish health is affected by these environmental parameters, especially pH and EC which can disrupt biological balance and cause stress.

B. Fish's Histological Preparate Observation

Tilapia (*Oreochromis niloticus*) were used in this research; this tilapia has good resilience but is still affected by the quality of the pond water. Tilapia's health in freshwater can be affected by various factors such as poor water quality, excessive population density, lack of nutrients that can inhibit growth, and risk from organic and inorganic waste contamination. Before the tilapia fish are placed in a large pond, they were first placed in the aquarium for 1 week to make fish adapt to the environment, slowly adjusting the temperature and water quality which may be different from the pond conditions and also reduce stress. Then fishes were released in the 2 ponds but in a special place to make it easy when the sampling time came.

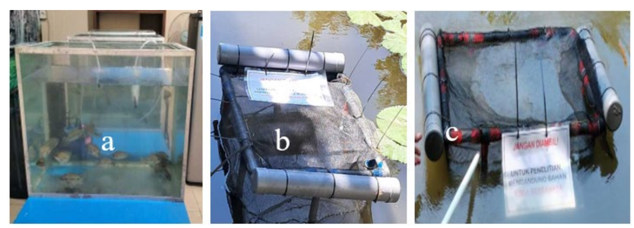

Fig. 8. Fishes rearing
(a. Aquarium; b. Chemical Pond; c. Physic Pond)

After a month, the fishes were taken from the ponds and process for histological preparate. Below are the following procedures from sampling, sectioning, making preparate, observing it using microscope and identify the damages to organs such as gill, liver and gill from fish.

Preparate that have been prepared observed by using Olympus CX 21 microscope with magnifications varying from objective 4x, 10x. and 40x.

1) Fish Gills

Changes that occur in the aquatic environment directly or indirectly will affect the structure and function of the gills. Histopathological changes that are commonly found in the gills are edema (cell swelling), hyperplasia, epithelial detachment from the underlying tissue, fusion (fusion) of lamellae secondary to the underneath, fusion of secondary lamellae due to hyperplasia of the gill epithelium, loss of secondary lamellar structure, and loss of secondary lamellar structure. (Saputra et al., 2013).

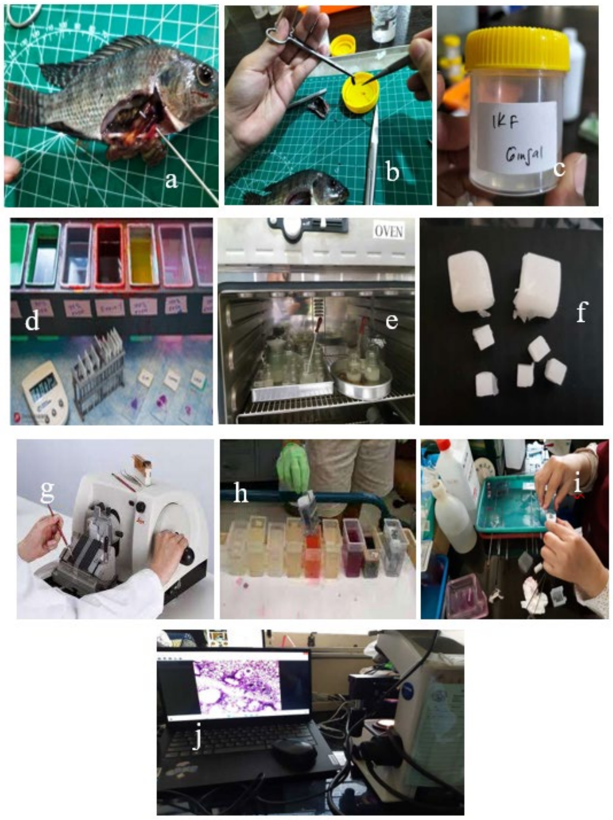

Fig. 9. Fishes' histological procedures
(a. Dissecting fish; b. Organ sampling; c. Fixation process; d. Dehydration and clearing; e. Paraffin infiltration; f. Paraffin block
g. Sectioning; h. Staining procedures; i. Mounting with entellan;
j. Observing with photomicroscope)

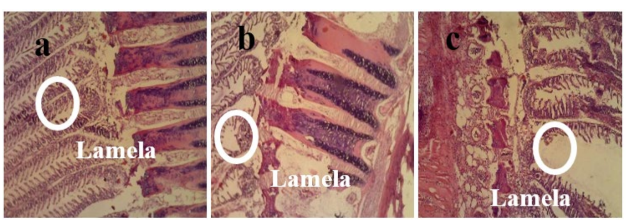

Fig. 10. Fish gills histology (10x magnification)
a. Control fish, b. Fish in chemical pond, C. fish in physical pond

Figure 10 shows there are differences in the lamella area both primary and secondary, fish lamellae in the pond of the Department of Chemistry and Physics are degraded due to the pH condition of the pond is not neutral, the possibility of pollutants in the pond so as to cause the gills in fish damaged by disrupting the primary and secondary lamellar tissue resulting in hyperplasia (Lu et al, 1995).

2) Fish Liver

The liver functions as a metabolic center and plays a role in the detoxification process, storage of nutrients and reproduction of various enzymes and hormones that support fish survival. The fish liver consists of hepatocyte tissue that functions for detoxification of toxins, metabolism, and bile production. The sinusoidal blood vessels present between the hepatocytes allow for the transportation of nutrients and the removal of waste substances. Kupffer cells help maintain the immune system by capturing foreign particles in the blood. The bile ducts channel bile produced by hepatocytes to support the digestive process. These structures allow the liver to fulfill its role as a vital organ in the fish body.

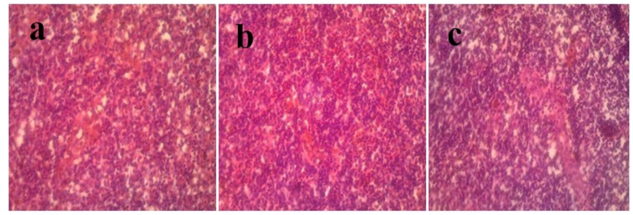

Fig. 11. Fish liver histology (Magnification 40 x)
a. Control fish, b Chemical Pond fish, c. Physics Pond fish

Figure 11 shows that the liver of the control fish is different from the liver of the fish in the chemical and physical ponds. in the chemical ponds it is suspected that the toxic substances that enter in large quantities are visible from the picture degenerating, cells losing the normal structure of the cell due to influences from within or from outside the cell. Cell degeneration is characterized by metabolic disturbances. This causes the accumulation of materials intracellularly and extracellularly which then leads to cell death and is a sign of the start of cell damage due to the presence of toxins (Fahrimal et al., 2016). The resulting toxic response will be greater along with the higher concentration of a compound that enters the body. whereas in the Physics pool the toxic substance that enters the body is relatively small and the liver detoxification function is good, so it does not experience damage.

3) Fish Kidney

The kidney in fish is the main organ in the excretory and osmoregulatory systems. The structure of the fish kidney usually extends parallel to the backbone. Its functions include regulation of ion and water balance (osmoregulation) and excretion of nitrogenous waste in the form of ammonia (in freshwater fish) or urea (in certain fish).

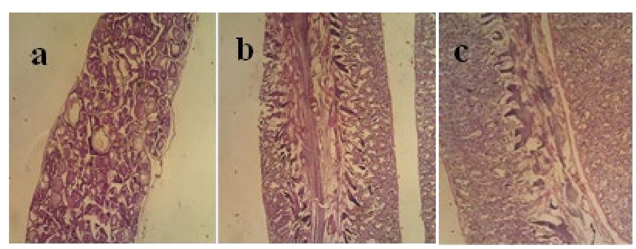

Fig. 12. Fish kidney histology (Magnification 40 x)
a. Control fish, b. Chemical Pond fish, c. Physical Pond fish

Figure 12 shows that there is histopathological damage to the kidneys of fish in chemical and physical ponds in the form of necrosis (cell death) of tubular cells. This damage is caused by the blockage of toxic compounds in the cells. Necrosis can be caused by trauma, biological agents (viruses, bacteria, fungi, and parasites), chemical agents such as toxic substances or interference with blood supply. Necrosis is the death of cells or tissues of living things and is the final stage of degeneration that is irreversible (Ersa, 2008). The same opinion stated by Takasima and Hibiya (1995) necrosis describes the state of decreased tissue activity characterized by the loss of some parts of the cell one after another from one tissue, which is histopathologically characterized by the appearance of cell boundaries and cell nuclei unclear or even disappear. According to Setyowati, et al (2010), the presence of toxic substances in the fish body can affect the histological structure of the fish kidney, cell instability in pumping sodium ions out of the cell causes increased fluid from outside the cell to enter the cell so that the cell is unable to pump enough sodium ions and cause the cell to swell and lose membrane integrity, so that the cell will release cell material out, then necrosis occurs and causes irregular cells and even lysis.

4. Conclusion

Based on the observation data of temperature, pH and EC parameters for chemical and physical pool water, the average temperature is 30 ⁰C, the pH in the chemical department pool has an acidic pH and the pH in the Physics department pool has an alkaline pH. While the average EC value in the Chemistry and Physics ponds are 2.5273 and 2.5218 µS/cm respectively. As for the observation of fish histology which includes gills, liver and kidneys, there is damage to these organs in both the Chemistry and Physics department ponds. This is suspected to be the presence of pollutants from the FSAD WWTP that are toxic in both ponds.

Acknowledgement

The authors would like to thank the Dean of the Faculty of Science and Data Analytics (FSAD) of Institut Teknologi Sepuluh Nopember for the financial and technical support under the 2024 Faculty Fund Tendik Research grant awarded to Zahrotul Istiqomah.

References

[1] Azmi, N., Yunashfi., dan A. Muhtadi, (2015), Struktur Komunitas Nekton di Danau Pondok Lapan Desa Naman Jahe Kecamatan Salapian Kabupaten Langkat.
[2] Chernova, O. F. (2010), Microstructure of Ssin derivatives as a reflection of phylogenesis of vertebrates. Russ. J. Dev. Biol., 41(5):326–335. Skripsi. Sumatera Utara: Universitas Sumatera Utara.
[3] Coulibaly S. Atse BC, Kouamelan EP, (2012), Histological alterations of gill, liver and kidney of black-chinned tilapia Sarotherodon melanotheron contaminated by heavy metals from Bietri Bay in Ebrie Lagoon, Cote d'Ivoire. International Journal of Science and Research. 3: 1970-1975.
[4] Darmono. (2001), Lingkungan Hidup dan Pencemaran: Hubungannya dengan Toksikologi Senyawa Logam. Jakarta (ID): Penerbit Universitas Indonesia.
[5] Demirak, A.; Yilmaz, F.; Levent, T. A. and Ozdemir, N, (2006), Heavy metals in water, sediment and tissues of Leuciscus cephlaus from a stream in southwestern Turkey. Chemosphere, 63: 1451-1458. Hutagalung HP. 1984. Logam Berat Dalam Lingkungan Laut. Oceania Lembaga Ilmu Pengetahuan Indonesia Jakarta. 9(1):11-20.
[6] Dua, A. D. and Gupta, N. (2005), Mercury toxicology as assessed through fish scales. Bull. Environ. Conta. Toxicol., 74:1105–1110.
[7] Ersa, I.M. 2008. Gambaran Histopatologi Insang, Usus Dan Otot Pada Ikan Mujair (Oreochromis mossambicus) Di Daerah Ciampea Bogor. Skripsi. Fakultas Kedokteran Hewan Institut Pertanian Bogor. Bogor.
[8] Fahrimal, Y., Rahmiwati, D. Aliza. (2016), Gambaran Histopatologis Ginjal Tikus Putih (Rattus Norvergicus) Jantan Yang Diinfeksikan Trypanosoma Evansi Dan Diberi Ekstrak Daun Sernai (Wedelia Biflora). Jurnal Medika Veterinaria. 10(2):2503-1600.
[9] Galadima, A. and Garba, Z. N. (2012), Heavy metals pollution in Nigeria: Causes and Consequences. Elixir Pollution, 45:7917-7922.
[10] Gyampo, M.; Kumi, M. and Zango, M. (2013), heavy metal concentration in some selected fishes in Tono irrigation reservation in Navrongo Ghana. J. Environ. Eart. Sci., 3(1):109-120.
[11] Imam Fachri, Hilal Fauzan, Novy Hapsari, Hafizh Aliyudin Amrullah, Bagus Hanafi (2023), Sistem Pengendalian Dan Pemantauan Kualitas Air Berbasis IoT, TECHNOPEX- Institut Teknologi Indonesia.
[12] Kusrini, P., Wiranto, G., Syamsu, I., & Hasanah, L. (2016), Sistem Monitoring Online Kualitas Air Akuakultur untuk Tambak Udang Menggunakan Aplikasi Berbasis Android. Jurnal Elektronika Dan Telekomunikasi.
[13] Lin-Sun, P.; Hawkins, W. E.; Overstreet, R. M. and Brown-Peterson, N. J. (2009), Morphological deformities as biomarkers in fish from contaminated rivers in Taiwan. Int. J. environ. res. Pub. Heal., 6:2307–2331.
[14] Lu, C.F. 1995. Toksikologi Dasar. Jakarta: Universitas Indonesia
[15] Maier, D.; Blaha, L.; Giesy, J. P.; Henneberg, A. and Köhler, H. R. (2014), Biological plausibility as a tool to associate analytical data for micropollutants and effect potentials in wastewater, surface water, and sediments with effects in fishes. Water Research. 72, 127-144.
[16] Rajeshkumar S, Munuswamy N. (2011), Impact of metals on histopathology and expression of HSP 70 in different tissues of Milk fish (Chanos chanos) of Kaattuppalli Island, South East Coast, India. Chemosphere. 83: 415–421.
[17] Riani E. (2010), Kontaminasi logam berat pada ikan budidaya dalam keramba jaring apung di Waduk Cirata. Jurnal Teknobiologi. 1(1): 51-61.
[18] Riani E. (2012), Perubahan Iklim dan Kehidupan Biota Akuatik (Dampak pada Bioakumulasi Bahan Berbahaya dan Beracun & Reproduksi). Bogor (ID): IPB Press.
[19] Setyowati, A., D. Hidayati, P.D.N. Awik, dan N. Abdulgani. 2010. Studi Histopatologi Hati Ikan Belanak (Mugil cephalus) di Muara Sungi Aloo Sidoarjo. Skripsi. ITS. Surabaya.
[20] Shikha, S. and Sushma, D. (2011), Effect of fly ash pollution on fish scales. Res. J. Chem. Sci., 19 1(9):24–28.
[21] Sneddon, E. J.; Hardaway, C. J.; Sneddon, J.; Boggavarapu, K.; Tate, A. S.; Tidwell, S. L. and Douvris, C. (2017), Determination of selected metals in rice and cereal by inductively coupled plasma-optical emission spectrometry (ICP-OES). Microchem. J., 134, 9–12.
[22] Widyaningrum, T. dan T. Suharyanti. 2010. Pengaruh Merkuri Klorida Terhadap Pertumbuhan dan Histopatologi Ginjal Ikan Nila (Oreochromis niloticus, Linn). Jurnal Seminar Nasional VIII Pendidikan Biologi.
[23] Takarina ND, Bengen DG, Sanusi HS, Riani E. (2013), Geochemical fractionation of copper (Cu), lead (Pb), and zinc (Zn) in sediment and their correlations with concentrations in bivalve mollusc Anadara indica from Coastal Area of Banten Province, Indonesia. International Journal of Marine Science. 3(30): 238-243.
[24] Zhang M, Cui Lijuan, Sheng L, Wang Y. (2009), Distribution and enrichment of heavy metals among sediments, water body and plants in Hengshuihu Wetland of Northern China. Ecological engineering. 35(4): 563-369.
[25] F. Venny dan E. Roza. 2014. Struktur Usus Ikan Ompok Hypophthalmus Dari Perairan Sungai Siak Kota Pekanbaru. Jurusan Biologi Fakultas Matematika dan Ilmu Pengetahuan Alam Kampus Bina Widya Pekan baru. JOM FMIPA Volume 1 No. 2 October 2014.
[26] Lestari, A. dan Zaifa, A. 2022. Penerapan Sistem Monitoring Kualitas Air Berbasis Internet of Things. Institut Teknologi Telkom Purwokerto. Open Access. Ledger, Vol. 1, No. 1, Feb. 2022.
[27] Y. Setiawan, H. Tanudjaja, and S. Octaviani, "Penggunaan Internet of Things (IoT) untuk Pemantauan dan Pengendalian Sistem Hidroponik," TESLA J. Tek. Elektro, vol. 20, no. 2, p. 175, 2019.
[28] A. H. Kadafi and U. B. Luhur, "Perancangan pengendalian suhu dan salinitas air pada aquarium ikan botana biru," vol. 3, no. 1, pp. 62–68.