JURNAL PERIKANAN
UNIVERSITAS GADJAH MADA
Terakreditasi Ristekdikti No: 158/E/KPT/2021

ISSN: 2502-5066 (Online)
ISSN: 0853-6384 (Print)
Vol. 27(2),123-131
DOI 10.22146/jfs.106986

The Influence of Pb Levels in Water on Histopathology of Gills and Kidneys of *Hemibagrus nemurus* (Valenciennes, 1840) in Siak River, Pekanbaru, Riau

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Submitted: 21 May 2025; Revised: 24 October 2025; Accepted: 13 November 2025; Published: 19 December 2025

ABSTRACT Waste metals from the Siak River in Indonesia's Riau Province can enter fish organs and change their structure and metabolic functions. This study looks for heavy metal concentrations in the water and structural organ alterations of *Hemibagrus nemurus* (Valenciennes, 1840). Fish and river water samples were collected at sites 1 (Limah Puluh district) and 2 (Rumbai Pesisir district). The Atomic Absorption Spectrophotometry (AAS) method tests kidney and gill Pb samples. Siak River Pb readings in locations 1 and 2 were 0.113 mg/L and 0.072 mg/L in January 2024 and 0.105 and 0.128 mg/L in October. Gill and kidney Pb were 0.0132 and 0.2726 mg/kg. Fish kidneys were reddish-black at two sites, while gills were bright red at site one and dark red at site two. In all samples, edema, fusion, hyperplasia, telangiectasis, and epithelial lifting indicate fish gill tissue injury. Kidney tissue abnormalities also indicate injury. It is concluded that Pb levels in the Siak River exceeded the permissible limit in 2024, resulting in edema, necrosis, degeneration, and damage to the kidneys and gills of fish. The ecosystem of the river may be harmed by elevated Pb levels in the water, which have also injured fish organs.

Keywords: Gill; histopathology; kidney; structure; Siak River

INTRODUCTION

The Siak River, which is the habitat of the baung fish, has been polluted. In 2013, the Siak River was polluted by heavy metals with the highest concentrations, namely iron 2.193 mg/L, zinc 1.954 mg/L, copper 0.526 mg/L, and lead 0.089 mg/L (Putri et al., 2014). The water quality of the Siak River in Pekanbaru City during high and low tide in 2016 during low tide contained heavy metal Pb ranging from 0.06 to 0.09 mg/L and Cd ranging from 0.003 mg/L (Yuliati et al., 2017).

This increasing environmental pollution is caused by numerous industrial activities, shipping activities, and direct waste disposal into the water. The large number of pollutants in the water will cause a decrease in dissolved oxygen levels in the water, which will disrupt the life of fish in the water (Setiyono & Yudo, 2008). Research by Syukriah et al. (2024) found that heavy metal content in waters exceeding the standard threshold of 0.3 mg/L will accumulate in the fish's body, such as Fe content of 1.19 mg/L in the water will accumulate in fish at 10 mg/kg. Where this result is above the standard value of Fe content in the fish body of 0.8 mg/kg. Pollutants that enter the water will experience 3 types of accumulation, namely physical, chemical, and biological. Accumulation of heavy metals in waters is biological through the food chain. Accumulation occurs when fish drink water or eat food that has been contaminated with heavy metals (Istarani & Pandebesei, 2014).

The gill organs function as the main respiratory organ that regulates the exchange of oxygen and carbon dioxide gases and regulates the exchange of salt and water in the body with the environment and the process of excreting waste containing nitrogen (Kasvarin et al., 2022). The gills are the first organs exposed to dissolved metals in water because they have gill lamellae consisting of layers of epithelial cells. The epithelial layer in the gill lamellae that is continuously exposed to heavy metals will cause changes in the structure of the gill lamellae (Yolanda et al., 2017). The kidneys function to help maintain blood composition by preventing waste accumulation. The kidneys also have a role in the process of secreting metabolic products such as ammonia and have an important function in maintaining homeostasis (Hapsari et al., 2022). The process of heavy metals entering the fish's body together with water, which is diffusely absorbed by the gills, then distributed to all body organs through the blood. The heavy metals that accumulate in organ tissue will damage the tissue so that physiological performance in organs in the body is disrupted (Annafia et al., 2024). This study aims to determine the levels of heavy metal lead (Pb) in waters, gill and kidney organs, as well as changes in the structure of gill and kidney tissue of the baung fish Hemibagrus nemurus (Valenciennes 1840) in the waters of the Siak.

MATERIALS AND METHODS

Materials

The materials used for the research were gills and kidneys of catfish, Siak river water, 0.9% physiological salt, 10% BNF (buffered neutral formalin), alcohol (70%, 80%, 90%, and absolute), xylol, histoplast paraffin (58°C), entelan, distilled water, hematoxylin-eosin (HE), and 20% nitric acid solution (HNO_3).

Methods

Water sampling and Pb determination

The gill and kidney organs, as well as water samples from the Siak River, were collected at two locations: location 1 (Lima Puluh district) and location 2 (Rumbai Pesisir district). The water samples were collected 500 mL below the water surface using a container. The water in the Siak River was tested for Pb heavy metal content using Atomic Absorption Spectrophotometry (AAS). The gill and kidney samples were weighed and placed in a furnace to be ashed for approximately 3 hours. The initial furnace temperature was raised every 30 minutes to 600°C and maintained for 2 hours. Next, the samples were removed from the furnace and allowed to cool to room temperature. 5 mL of concentrated HNO☐ was added to the cold sample and heated on a hot plate at 100 °C. The sample was transferred to a 10 mL flask, and 5 mL of distilled water was added to bring the volume to 10 mL. The mixture was then filtered through filter paper. The sample was transferred to a closed test tube. A working standard Pb solution was prepared with five concentration points. The working standard solution and sample were analyzed on a graphite furnace atomic absorption spectrophotometer (AAS) at a wavelength of 283.3 nm (Safitri et al., 2019). The water, Siak River, gill, and kidney samples were tested for Pb heavy metal content using Atomic Absorption Spectrophotometry (AAS) at the Chemical Testing and Analysis Laboratory, Faculty of Engineering, University of Riau, Pekanbaru, Indonesia.

Kidney organ preparations of baung fish

The preparation of fish gill and kidney organs was carried out at the Microtechnical Laboratory, Department of Biology, Faculty of Mathematics and Natural Sciences, University of Riau. The gills and kidneys were washed with 0.9% physiological saline for 15 minutes, then fixed with a 10% Neutral Buffered Formalin (NBF) solution for 72 hours. Then, the gills were soaked in 20% HNO☐ for 16 hours. The following process was dehydration in graded alcohol (80%, 90%, and 96%) for three hours each, followed by immersion in absolute alcohol solutions I, II, and III for one hour each. The clearing stage was carried out in xylol I, II, and III solutions for one hour each. Samples were inserted into paraffin I (60 minutes) and paraffin II (40 minutes) for the infiltration stage. Samples were then embedded in liquid paraffin in a cardboard box and cooled to harden in the freezer, forming paraffin blocks.

The gill and kidney organs in paraffin blocks were sectioned using a microtome with a 6-μm thickness. Pieces of paraffin tape were glued to a glass slide and stored in a 38 °C oven for two days before deparaffinization. The deparaffinization stage is carried out by immersing the histological slides in xylene I, II, and III for 2 minutes each, then in absolute alcohol, 96%, 90%, 80%, 70%, 60%, 50%, 40%, and 30% alcohol for 2 minutes each, and then in distilled water for 5 minutes. The preparations were then stained with hematoxylin for 7 minutes and soaked in tap water for 10 minutes, followed by 5 minutes in distilled water. The sample preparations were air-dried and then placed into eosin staining solution for 7 minutes, followed by dipping in 70%, 80%, and 90% alcohol, absolute alcohol for two dips each, and xylol I, II, and III for 5 minutes each. The final stage includes covering the sample preparations with a cover glass using Entellan. Then, observations are made on the sample preparations.

Statistical analysis

Data were analyzed descriptively, qualitatively, and quantitatively. Qualitatively, observations were made on changes in the color of the gill and kidney organs. Microscopic changes in the gill tissue, such as the shape of cells in the primary lamella tissue and secondary lamella tissue. Microscopic changes in kidney organs, such as parenchymal degeneration, hydropic degeneration, fatty degeneration, and cell necrosis. The formula for calculating the average percentage of changes in the structure of the gill and kidney organs is as follows (Lubis *et al.*, 2014).

Tissue Damage Percentage (%) = Number of damaged cells / Total cell count x 100%.

RESULTS AND DISCUSSION

The results of the lead (Pb) heavy metal content test in the Siak River waters in January 2024, at Lima Puluh district, were 0.113 mg/L, and at Rumbai Pesisir district, they were 0.072 mg/L. Then, in October 2024, the Lima Puluh district had a concentration of 0.105 mg/L, and the Rumbai Pesisir district had a concentration of 0.128 mg/L (Table 2). The lead (Pb) levels in both locations have exceeded the water quality standard limit. The normal standard value for lead (Pb) levels in water, based on PP No. 22 of 2021 concerning water quality management and water pollution control, has a lead tolerance limit of 0.03 mg/L for Class I, 0.03 mg/L for Class II, 0.03 mg/L for Class III, and 0.5 mg/L for Class IV. For Class I water, it can be used for drinking water. Class II water can be used for water recreation facilities, freshwater fish farming, and irrigating crops. Class III water can be used for freshwater fish farming and irrigating crops. Class IV water can be used to irrigate crops and for other purposes that are like these uses.

Table 1. Scoring of fish tissue damage.

Score	Percentage (%)	Description
0	0	No cell damage
1	1-25	Light cell damage
2	26-50	Moderate cell damage
3	51-75	Moderately heavy cell damage
4	76-100	Heavy cell damage

(Pantung *et al.*, 2008)

The Siak River can also be affected during water sampling, particularly when samples are taken during the summer. The tidal cycle, currents, waves, and seasons influence the high and low levels of heavy metals. During the rainy season, the content of heavy metals in water tends to be lower due to dissolution, whereas in the dry season, it tends to be higher because heavy metals settle to the bottom of the water. Heavy metals that are difficult to dissolve undergo a dilution process influenced by tidal current patterns in the water, which eventually sink to the bottom and settle in the sediment, indicating the accumulation of heavy metals in the sediment (Muhtaroh *et al.*, 2024).

Table 2. The levels of heavy metal lead (Pb) in the waters of the Siak River, Pekanbaru City.

Research Location	Lead (Pb) heavy metal content	PP quality standard No. 22 of 2021
January 2024		
Lima Puluh district	0.113 mg/L	
RumbaiPesisir district	0.072 mg/L	
		0.03 mg/L
October 2024		
Lima Puluh district	0.105 mg/L	
Rumbai Pesisir district	0.128 mg/L	

The results of this study at the fish retrieval location in the Lima Puluh Pekanbaru district showed that the gills and kidneys contained lead below the normal safe standard threshold in organs, specifically 0.0132 mg/kg in the gills, 0.0065 mg/kg in the meat, and 0.2726 mg/kg in the kidneys. At the fish retrieval location in Rumbai Pesisir district, the lead levels in the internal organs of the fish, which were still below the standard organ quality levels, were 0.1504 mg/kg in the gills and 0.2475 mg/kg in the kidneys (Table 3). According to Regulation No. 5 of 2017 of the Food and Drug Supervisory Agency (BPOM), the safe lead level in organs for consumption is 0.20 mg/kg. Lead that is absorbed in the digestive system will bind to erythrocytes in the bloodstream. Heavy metals that accumulate in the internal organs of fish will interfere with the function of these organs. Lead that accumulates in the fish's body becomes free radicals, which can cause damage to the fish's internal organs, such as the gills, digestive tract, liver, and kidneys (Paundanan *et al*., 2020).

The results of macroscopic observations on the gill organs of baung fish in Lma Puluh District and Rumbai Pesisir District are presented in Figure 1. The macroscopic structure of the gills of baung fish consists of gill arches, gill filaments, and gill rakers. The gill organs in the Lima Puluh district are pale red, while in the Rumbai Pesisir district, they are dark red. Hermawanto's research (2020) found that the gills of snakehead fish are pale red due to the polluted waters of Lake Lubuk Siam and the Sibam River, resulting from mining activities. The characteristics of typical fish gills are fresh red with a slight coating of mucus (Putra, 2014). The results of observations of the macroscopic structure of the kidney organ of the baung fish are located between the vertebral column and the swim bladder, above the abdominal cavity, outside the peritoneum, below the spine, and dorsal aorta (Wagiman *et al*., 2014). In general, fish kidneys have an elongated and flat shape, consisting of two lobes, namely the right and left lobes, that are fused in the posterior part. The color of the kidneys of fish in the Lima Puluh district and Rumbai Pesisir district is blackish red (Figure 2). Normal kidneys are generally reddish-black in color (Paramita, 2020). This is in accordance with the research of Paramita (2020), which indicates that the normal kidneys of baung fish are blackish-red. If the kidneys change color to pale red, it can be caused by exposure to nephrotoxic substances (Fahriyansyah *et al*., 2021).

Table 3. Lead levels in the internal organs of baung fish from the waters of the Siak River, Pekanbaru.

Organs of Baung fish	Lead Level (mg/kg)		Standard quality lead content (BPOM No. 5 of 2017)
	Lima Puluh district	Rumbai Pesisir district	
Gill	0.1752	0.1504	0.20 mg/kg
Kidney	0.2726	0.2475	

The results of observations of the gill tissue of the baung

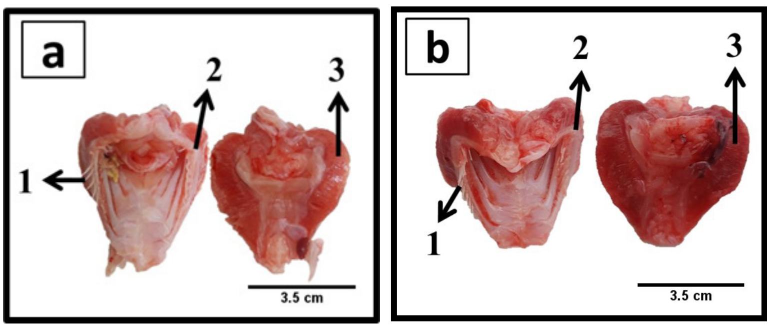

Figure 1. The gill organs of the baung fish a. Lima Puluh district, b. Rumbai Pesisir district, (1) gill rakers, (2) gill arch bones, (3) gill filaments.

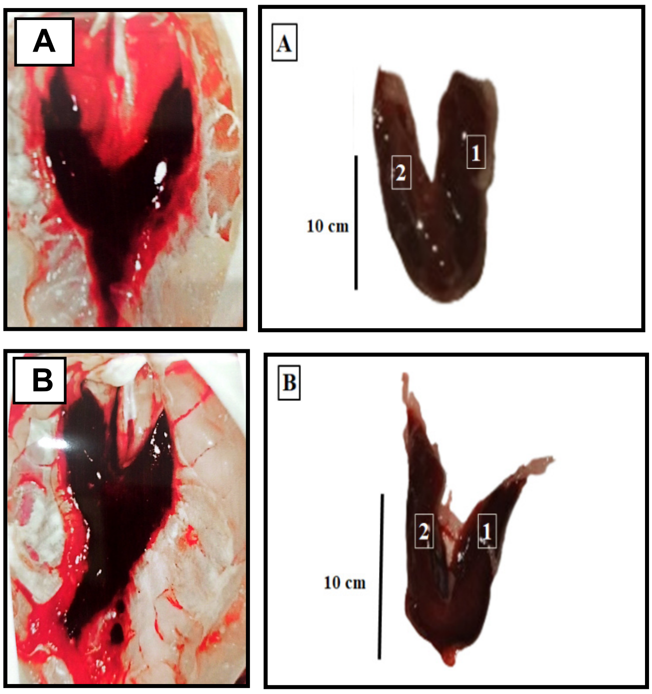

Figure 2. Morphology of the kidneys of baung fish from the waters of the Siak River. A. Lima Puluh district and B. Rumbai Pesisir district are reddish black: 1. Right lobe, 2. Left lobe.

fish showed damage to the tissue structure, marked by edema (swelling of cells), hyperplasia (increased cell production), and lamella fusion (fusion of secondary lamellae) (Figures 3 and 4). The scoring value obtained for the damage to the gill tissue of the baung fish in the waters of the Siak River, Lima Puluh District, and Rumbai Pesisir District is presented in Table 4. The level of damage to the gills of baung fish in the Lima Puluh district and Rumbai Pesisir district showed mild and moderate damage. Both locations have different levels of gill tissue damage. In the edema damage in the secondary lamella of the gills, Lima Puluh District has the highest percentage at 44.04%, compared to Rumbai Pesisir District at 35.62%. Epithelial lifting damage to the gill tissue in the Rumbai Pesisir district has the lowest percentage of 8.46%.

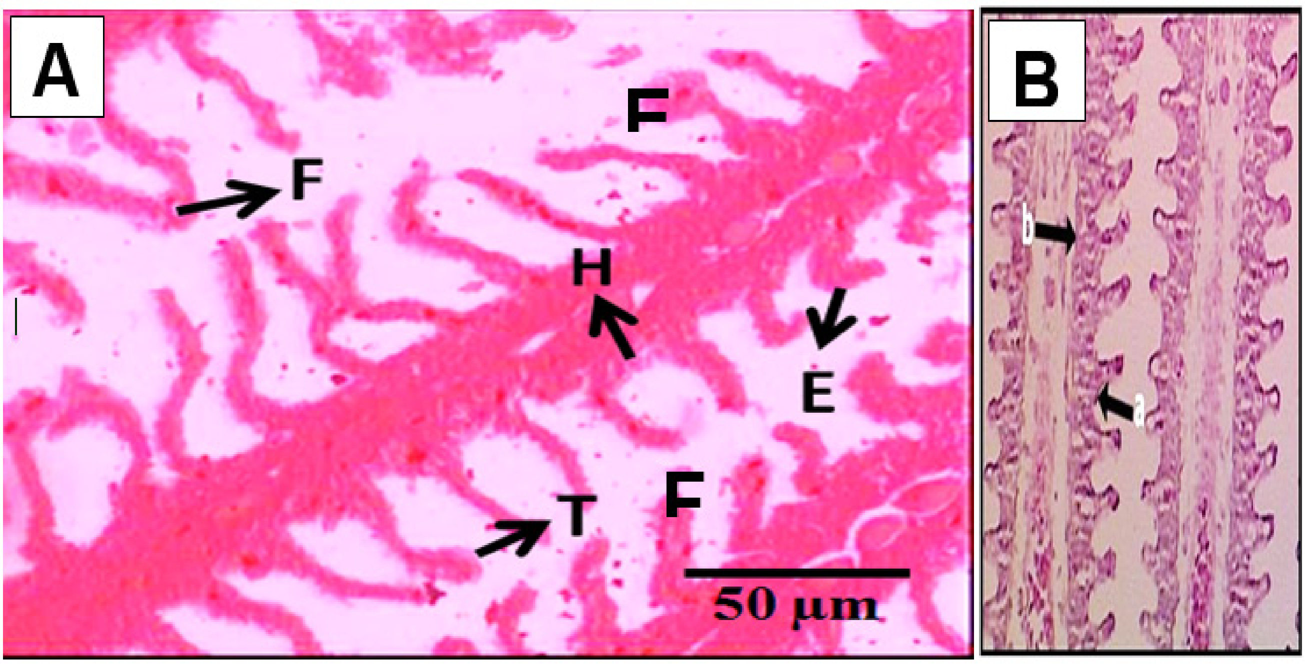

Figure 3. Cross-section of the gill lamella of baung fish. A. Lima Puluh district, B. Normal Gill. edema (E), fusion (F), epithelium lifting (EP), hyperplasia (H), and telangiectasis (T). a. secondary lamellae, b. primary lamellae.

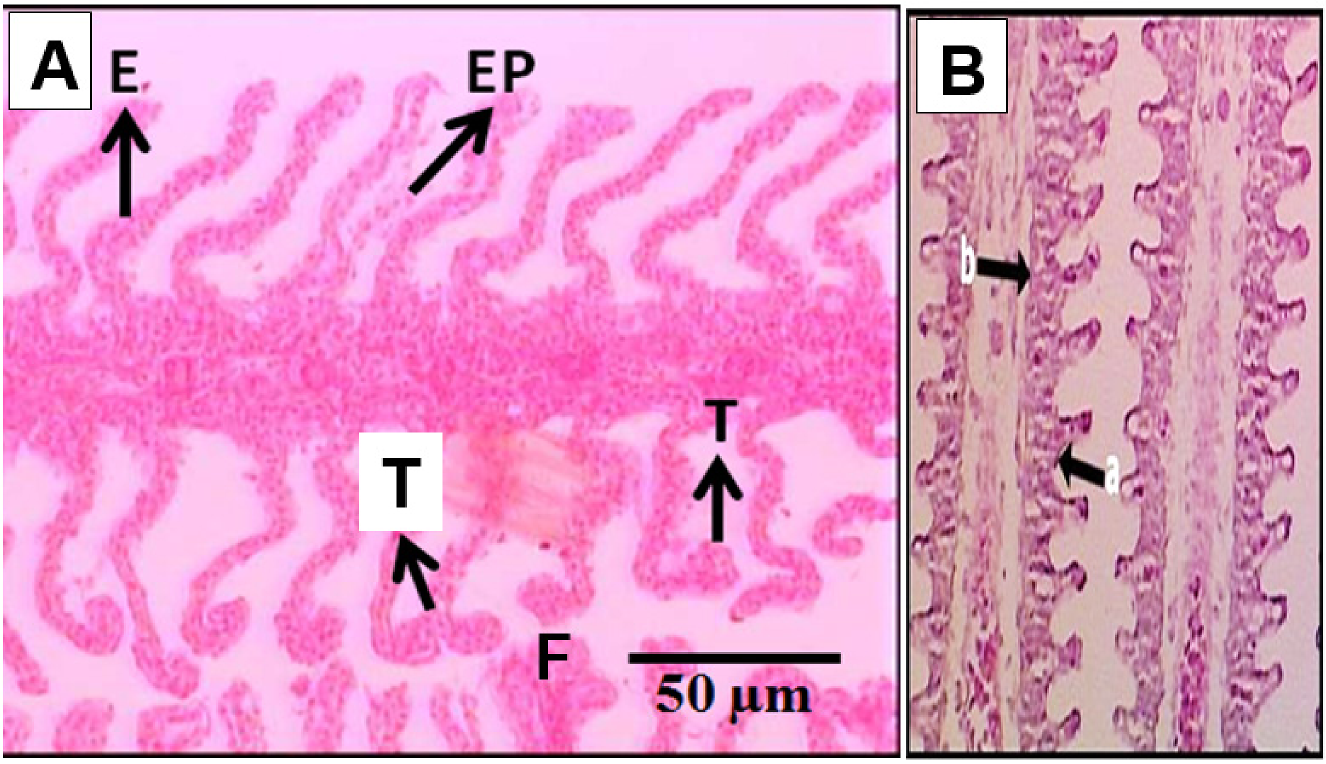

Figure 4. Cross-section of the gill lamella of baung fish. A. Rumbai Pesisir district, B. Normal Gill. Edema (E), fusion (F), epithelium lifting (EP), hyperplasia (H), and telangiectasia (T). a. Secondary lamellae, b. Primary lamellae.

Table 4. Average percentage and scoring value of gill organs of baung fish that experienced changes in the microscopic structure of the gills.

Location	Number of samples	Edema (%)	Epithelial lifting (%)	Hyperplasia (%)	Lamellar Fusion (%)	Telangiectasis (%)
Lima Puluh District	3	44.04	14.24	23.31	11.91	31.08
Scoring value		2	1	1	1	2
Rumbai Pesisir District	3	35.62	8.46	26.77	16.92	17.51
ScoringValue		2	1	1	1	1

Note. Score value 0=not damaged, 1=light (<30%), 2=moderate (30%-70%), 3=severe (>70%)

The gill tissue of the baung fish in this study experienced edema in the secondary lamella of the gills. Edema damage is the swelling of a cell or tissue due to being filled with fluid in the secondary lamella. Blood flow obstruction can be caused by physical trauma, contamination, and disruption of the circulatory system resulting from pathogens in the lamella. Edema that occurs in the tissue can reduce the efficiency of gas diffusion, and in more severe conditions, it can cause death in fish (Juanda *et al.*, 2023). Gill damage that shows edema accompanied by the lifting of the epithelial cells of the lamella is the first sign of gill damage. Edema in the lamella occurs due to the body's defense response to exposure to toxic substances contained in the water that is absorbed into the fish's body (Putri *et al.*, 2022).

The gills that experience edema will then undergo an epithelium-lifting process in the secondary lamella, which causes a decrease in the epithelium's ability to capture dissolved gases. Epithelium lifting is damage to the gill tissue characterized by the lifting of the epithelium layer from the tissue so that it does not appear to be attached to the basal membrane of the secondary lamella. The lifted epithelial layer is caused by mild swelling that occurs in the cells due to the entry of fluid (Juanda *et al.*, 2023). The thin gill epithelial layer, directly connected to the external environment, makes the gills susceptible to exposure to pollutants in the water (Idzni *et al.*, 2020). Hyperplasia is characterized by the production of excessive epithelial cells, resulting in a significant accumulation of cells in the gill lamella.

Additionally, hyperplasia also occurs due to the excessive division of chloride cells in the gill lamella (Manik *et al.*, 2023). Gill tissue damage in the form of hyperplasia is evident in swollen tissue, where the cell structure inside is no longer clear, yet the tissue epithelium remains (Juanda & Edo, 2018). Hyperplasia can also cause thickening of the epithelial tissue located at the end of the filament, resulting in a baseball bat-like shape (distal clubbing), or it can be characterized as thickening of the epithelial tissue near the base of the lamella (basal hyperplasia) (Prasetyo *et al*., 2022).

Lamellar fusion results in both sides of the secondary lamella with other secondary lamellae (Figures 3 and 4). Lamellar fusion is the next stage of hyperplasia that occurs continuously, so that lamellar fusion is included in the category of severe damage. Damage to lamella fusion in gills exposed to heavy metals can result in adhesion between secondary lamellae, thereby reducing the surface area of the gills in carrying out the respiration process (Musada *et al*., 2022). The fusion of lamellae that occurs in the gill lamellae disrupts blood circulation in the gills and compromises the fish's body metabolism, ultimately leading to death (Prasetyo *et al*., 2022). Telangiectasis is the widening of capillaries due to blood in the secondary lamella experiencing damming and the tip experiencing enlargement, like a balloon bubble. Telangiectasis that occurs continuously causes the epithelial cells of the secondary lamella to become pillar cells. Rapid blood circulation causes many erythrocytes to accumulate at the tip of the lamella and experience enlargement (Juanda *et al*., 2024).

The microscopic structure of the kidney consists of Bowman's capsule (glomerulus), proximal convoluted tubule, loop of Henle, and distal convoluted tubule (Table 5).

The average percentage of normal kidney cells (Table 5) in the Lima Puluh district was 61.87%, and in the Rumbai Pesisir district, it was 73.29%. The number of normal kidney cells in the Rumbai Pesisir district was higher than in the Lima Puluh district. Kidney tissue that underwent cell changes was characterized by abnormalities such as fatty swelling and necrosis. The total amount of kidney damage in the Lima Puluh district is glomeruli experiencing 4.18% parenchymal degeneration, 35.71% hydropic degeneration, 9.6% fatty degeneration, 17.24% necrosis, and 33.25% normal cells. The proximal convoluted tubule experienced 10.85% parenchymal degeneration, 19.45% hydropic degeneration, 34.91% fatty degeneration, 24.35% necrosis, and 10.4% normal cells. The loop of Henle experienced 9.78% parenchymal degeneration, 19.02% hydropic degeneration, 39.85% fatty degeneration, 21.84% necrosis, and 9.47% normal cells. In the distal convoluted tubule, there was 12.08% parenchymal degeneration, 17.91% hydropic degeneration, 33.75% fatty degeneration, 27.5% necrosis, and 8.75% normal cells.

Table 5. Average percentage and scoring value of tissue damage in the kidney organs of baung fish in the Siak River waters of Pekanbaru.

Sampling Location	Kidney tissue	Percentage of tissue damage in the kidneys				
		DP (%)	DH (%)	DM (%)	N (%)	SN (%)
Lima Puluh district	Glomerulus	4.18	35.71	9.6	17.24	33.25
	scoring value	1	2	1	1	2
	Proximal convoluted tubule	10.85	19.45	34.91	24.35	10.4
	Scoring value	1	1	2	1	1
	Loop of Henle	9.78	19.02	39.85	21.84	9.47
	Scoring value	1	1	2	1	1
	Distal convoluted tubule	12.08	17.91	33.75	27.5	8.75
	Scoring value	1	1	2	2	1
Rumbai Pesisir district	Glomerulus	4.26	30.23	3.29	36.82	25.38
	scoring value	1	2	1	2	2
	Proximal convoluted tubule	10.96	22.63	25.84	24.79	15.75
	Scoring value	1	1	2	1	1
	Loop of Henle	10.58	19.26	23.36	27.27	19.51
	Scoring value	1	1	1	2	1
	Distal convoluted tubule	9.94	19.71	24.41	33.27	12.65
	Scoring value	1	1	1	2	1

Note. DP= Degeneration of parenchymal; DH=Degeneration of hydropic; DM=Degeneration of fatty swelling; N= Necrosis; SN= Cells of normal.

Damage to the structure of the baung fish kidney in Rumbai Pesisir district (Table 5, Figure 5) was observed, with the glomeruli experiencing 4.26% parenchymal degeneration, 30.23% hydropic degeneration, 3.29% fatty degeneration, 36.82% necrosis, and 25.38% normal cells. The proximal convoluted tubule experienced 10.96% parenchymal degeneration, 22.63% hydropic degeneration, 25.84% fatty degeneration, 24.79% necrosis, and 15.75% normal cells. The loop of Henle experienced 10.58% parenchymal degeneration, 19.26% hydropic degeneration, 23.36% fatty degeneration, 27.27% necrosis, and 19.51% normal cells. The distal convoluted tubule experienced 9.94% parenchymal degeneration, 19.71% hydropic degeneration, 24.41% fatty degeneration, 33.27% necrosis, and 12.65% normal cells. Kidney damage occurs when hazardous substances enter the fish's body. This is supported by previous studies, which explain that hazardous substances enter the fish's body through the gills and then spread through the blood to the kidneys. High levels of toxins in the kidneys are caused by the continuous intake of hazardous substances, which makes it difficult for the kidneys to filter toxins (Billah & Yusni, 2023).

The average percentage of kidney cells that experienced the highest damage in the Lima Puluh district was fatty degeneration in the loop of Henle, with a value of 39.85% and a scoring value of 2, which is considered moderate damage. The average percentage of kidney cells that experienced the highest damage in the Rumbai Pesisir district was necrosis in the glomerulus, with a value of 2, at 36.82%, and was classified as moderate damage. The results showed that the highest average percentage of parenchymal degeneration was in the distal convoluted tubules of Lima Puluh district, at 12.08%, and in the proximal convoluted tubules of Rumbai Pesisir district, at 10.96%, which had a scoring value of 1, indicating mild classification. Parenchymal degeneration is the mildest reversible damage, characterized by swelling in cells and the cytoplasm becoming cloudy and granular. (Firdauzi, 2018).

The highest average percentage of hydropic degeneration was observed in the glomerulus at 35.71% in Lima Puluh District and 30.23% in Rumbai Pesisir District, and also in the glomerulus, which had a scoring value of 2, indicating a moderate classification. These cell changes

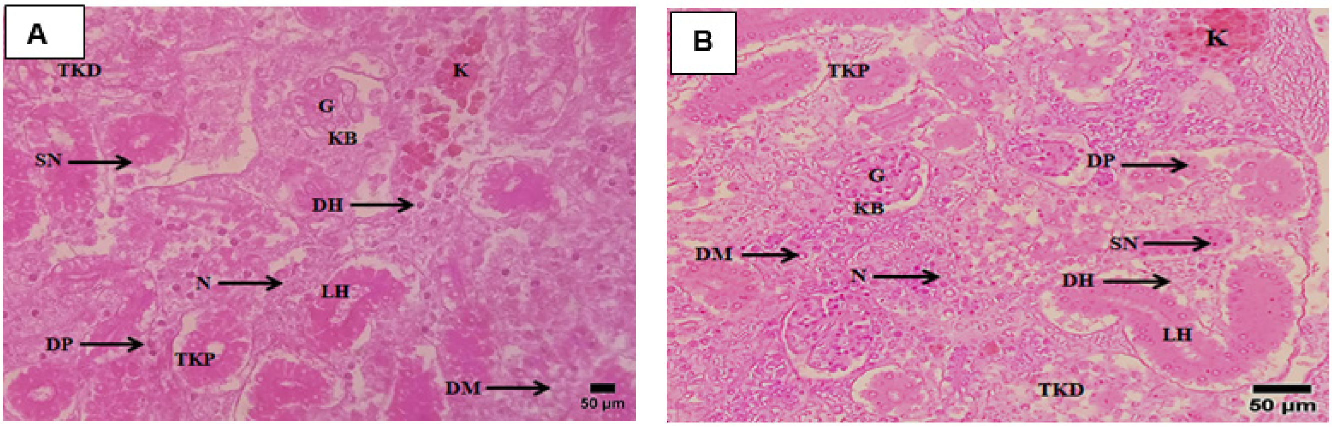

Figure 5. Cross-section of the kidney tissue of baung fish (A) Lima Puluh district (B) Rumbai Pesisir district, (KB) = Bowman's Capsule, (G) = Glomerulus, (TKP) = Proximal Convoluted Tubule, (LH) = Loop of Henle, (TKD) = Distal Convoluted Tubule, (Nk) = Necrosis, (DP) = Parenchymal Degeneration, (DH) = Hydropic Degeneration, (DM) = Fatty Degeneration, (K) = Congestion and (SN) = Cells of Normal. Magnification 50 µm.

occur when cells are unable to maintain ionic homeostasis, and this degenerative fluid is characterized by vacuolated cytoplasm. The vacuole appears clear, and the nucleus is in the middle (Baskara *et al*., 2019). Infiltration of kidney cells that experience inflammation/congestion is a reaction that causes inflammation of the blood vessels. When toxic substances enter the fish's body, especially the kidneys, the primary response is the accumulation of fluid from the blood vessel system and the movement of other blood components to unaffected areas. Dilated blood vessels in this condition are referred to as congestion (Billah & Yusni, 2023).

Necrosis is a condition of decreased tissue function characterized by the gradual loss of cell parts in a tissue. This process causes cell death in a relatively short time. Cell or tissue death that occurs during the process of cell degeneration in living things is the final stage of degeneration, which is irreversible and cannot be restored (Safitri *et al*., 2022). Symptoms of necrosis begin with hypertrophy and lysis. Hypertrophy is characterized by tissue damage that results in an enlargement of organ size due to an increase in cell size. As a result, cells become separated from each other. Hypertrophy can occur due to the blockage of toxic compounds, even at low concentrations. Lysis can inhibit cell wall synthesis or cause damage to the cell wall (Mandia *et al*., 2013).

CONCLUSION AND RECOMMENDATION

Conclusion

The water quality of the Siak River in January 2024 in Lima Puluh District was 0.113 mg/L, and in Rumbai District, it was 0.072 mg/L. Lead levels in Lima Puluh District were 0.1752 mg/kg in the gills and 0.2726 mg/kg in the kidneys, and in Rumbai District, they were 0.1504 mg/kg in the gills and 0.2475 mg/kg in the kidneys. Pb levels in the kidneys were above the quality standard (0.20 mg/kg). Damage to the gill structure of the catfish included edema, epithelial removal, hyperplasia, fusion, telangiectasis, and kidney tissue damage in the form of parenchymal degeneration, hydropic degeneration, fatty degeneration, necrosis, and congestion. Gill tissue damage (edema 44.04% and telangiectasis 31.08%) and kidney (fatty degeneration in the loop of Henle 39.85%) in Lima Puluh District, and gill damage (edema 35.62%) and kidney (necrosis in the glomerulus 36.82%) in Rumbai District are moderate damage.

Recommendation

This research is recommended for fish research in molecular physiology.

AUTHORS' CONTRIBUTIONS

Y: Researching ideas, data analysis, and manuscript preparation; SPH: Researching data analysis, manuscript preparation, and funding; UP: Researching data analysis, manuscript preparation, and funding.

ACKNOWLEDGEMENT

This research has been funded by the 2024 PNBP research fund of the Faculty of Mathematics and Natural Sciences.

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How to Cite this Article Yusfiati, Y., S.H. Putri & U. Prameswari. 2025. The influence of Pb levels in water on histopathology of gills and kidneys of *Hemibagrus nemurus* (Valenciennes, 1840) in Siak River, Pekanbaru, Riau. Jurnal Perikanan Universitas Gadjah Mada. 27 (2): 123-131. https://doi.org/10.22146/jfs.106986