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Heavy Metal Content of Cadmium in Tilapia from Taliwang Swamp Lake, West Sumbawa Regency

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Abstract: Research on the heavy metal Cd in fish is crucial to protect humans as consumers from harmful health impacts. This study aimed to determine the cadmium (Cd) content in tilapia (*Oreochromis mossambicus*) from Taliwang Swamp Lake (TSL). The specific benefit of this study is to protect consumers who consume fish from Cd contamination. This study was conducted in TSL waters. There are two research stations, one located in the eastern part and the other in the western part of the lake. Data collection was carried out using gill nets. Four tilapia samples were taken at each station. The tilapia samples were then wrapped in plastic bags and stored in sample boxes. The research samples were then analyzed at the West Nusa Tenggara Health, Testing and Calibration Laboratory Center. Data analysis was carried out by taking tilapia muscle tissue and analyzing metal content, especially Cadmium (Cd), using an Atomic Absorption Spectrophotometer. Measurement of heavy metals in tilapia tissue was carried out by adding concentrated HNO_3 and $HClO_4$, heated at 60-70ºC for 2-3 hours until the solution became clear. The samples were ready to be measured by AAS using an air-acetylene flame. The conclusion of this study was that the heavy metal content of Cd in tilapia (*O. mossambicus*) originating from TSL was 0.03 mg/kg (ppm).

Keywords: Cadmium (Cd); Tilapia; Taliwang Swamp Lake.

Introduction

Many organisms can live in aquatic ecosystems. Tilapia fish is one of the many fish species that can live in lake waters. Fish are one of the species that depend on aquatic ecosystems for their lives. Taliwang Swamp Lake, as a freshwater ecosystem, serves as a habitat for various biological processes that support different types of aquatic life. The Taliwang Swamp Lake (TSL) area is a freshwater body of water located in West Sumbawa Regency with a total area of 819.20 ha according to Ministerial Decree No. 589/Menhut-II/2009 concerning the determination of Forest Areas and Marine Conservation Areas in West Nusa Tenggara Province on October 2, 2009 [1; 2]. In the Taliwang swamp lake, there are various species of fish. Tilapia (*Oreochromis mossambicus*) is one species of fish found in the TSL. This fish can serve as a bioindicator of the existing ecosystem.

TSL is administratively located within two sub-districts: Taliwang District (covering Seloto and Pakirum Villages, as well as Sampir Village) and Seteluk District, including Meraran Village. Geographically, Lake Lebo is situated between 8°34'0"S and 116°13'0"E, characterised by hilly to mountainous topography. The lake's elevation is approximately 200-400 m above sea level and is characterised by regosol and lithosol soil types [1].

TSL can play a significant role in enhancing the local economy of the surrounding community by leveraging its high natural resource potential. This includes serving as a freshwater fish farming and cultivation area, a water source for agricultural irrigation, and offering potential for ecotourism. Another role of Taliwang Swamp Lake is to provide flood control for Taliwang City. During the dry season, the lake's water level decreases, leaving areas of the lake seemingly dry [1; 3].

Due to the fishing and cultivation of freshwater fish, and the use of insecticides, herbicides, fungicides, and fertilizers by local communities, there is a risk that the water and organisms in TSL will be contaminated by heavy metals. Heavy metals that have been found include cadmium (Cd), mercury (Hg), and other heavy metals [4].

The increasing trend of cadmium (Cd) in water bodies such as lakes, especially at the beginning of the rainy season, requires vigilance. According to [5], heavy metals entering the water will spread and accumulate in sediments, which in turn will accumulate in the bodies of aquatic organisms such as fish. Furthermore, Cd is a persistent heavy metal, so if it contaminates living organisms, it will be harmful. Humans who consume fish contaminated with cadmium (Cd) can accumulate this heavy metal, which is very dangerous, causing poisoning and, in humans, bone tissue damage [6].

Rising water temperatures will accelerate the accumulation of heavy metals in fish tissues. Increasing water temperatures will tend to increase the accumulation and toxicity of heavy metals, particularly Cd. [7] stated that fish exposed to heavy metals such as Hg, Pb and Cd tend to

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accumulate more at temperatures above 30°C compared to room temperature. This may occur due to the increased metabolic rate of aquatic organisms such as fish [8].

Heavy metal accumulation in fish tissue, such as tilapia (*O. mossambicus*), is more likely to occur in lake waters. Fish living in confined habitats, such as rivers and lakes, are more susceptible to heavy metal contamination than fish living in open waters. Cd accumulation in fish tissue occurs after Cd adsorption from buffered water through food, such as algae contaminated with Cd [9].

Rivers and lakes can be easily contaminated by various types of heavy metals, such as Cadmium (Cd) [10; 11]. Water and soil pollution can originate from wastewater, garbage, and other pollutants, such as the use of pesticides, fertilisers, and detergents in daily life [12]. Researcher observations show that farmers around TSL consistently fertilize their rice fields to ensure their growth, such as rice [4].

Many plant species grow in TSL. These plants have the ability to act as biofilters, specifically binding, filtering, and trapping pollution in the wild in the form of excess sediment, garbage, and other household waste. This function is very beneficial in improving water quality [13]. Various types of plants can function as natural agents of bioremediation because they can absorb heavy metals in the environment, such as Fe, Mn, and Cr. Other metals that can be absorbed by plants are Copper, Cobalt, Nickel, Lead, Zinc, and Cadmium. This process of heavy metal absorption by plants is known as biosorption [14]. Taliwang Swamp Lake receives water and sediment sources from various surrounding water sources that flow into the lake.

Heavy metal pollution in water bodies has been extensively studied in various water bodies in Indonesia, as reported by [15], which showed that levels of heavy metals/pollutants in the water and sediment at the Cisadane River estuary ranged from Lead ≤ 0.001-0.005 ppm, Cadmium ≤ 0.001-0.001 ppm, and Copper ≤ 0.001-0.001 ppm.

Heavy metal content in fish tissue has been extensively studied. Several studies have concluded that exposure to heavy metals such as Cd, Cu, and Pb has been found in Snakehead fish (*Channa striata*), Rice paddy eels (*Monopterus albus*), and Climbing perch (*Anabas testudineus*) (Khairuddin, dkk, 2023). The results of research by [17], in Snakehead fish found heavy metal content of Mercury 6.68 ppb, Cadmium, 2.32 ppb, Copper, 24.50 ppb and Lead 1.60 ppb. The results of subsequent studies concluded that there was a heavy metal content of Pb in Snakehead fish of 11.01 ppm and in Tilapia fish of 10.83 ppm [18]. [19] showed that there was a heavy metal content of Cadmium 0.16 ppm, Copper, 0.79 ppm and Lead, 0.22 ppm in Snakehead fish. Accumulation of heavy metal Copper was detected in the gills and liver of Snakehead fish (*Channa striata*) [20; 21].

Heavy metals have also been detected in other fish species, such as the Rice paddy eel (*Monopterus albus*). Research concluded that the Cd content in the climbing perch was 84 ppb [22]. In addition to the climbing perch and snakehead fish, tests on Beloso fish meat found Lead (Pb) content of 0.005 mg/kg (ppm), Cadmium (Cd) of 0.032 mg/kg, and Copper (Cu) of 0.293 mg/kg [23]. These various research findings indicate that fish tissues can accumulate various types of heavy metals, including mercury, Lead, and Cadmium.

The main reason heavy metals are hazardous pollutants is that they are non-degradable by living organisms in the environment and accumulate in the environment, primarily settling at the bottom of waters. In addition, heavy metals can enter the trophic level of the food chain through biomagnification and bioaccumulation [24; 25].

Considering the importance of heavy metals in aquatic organisms, as a study material for determining development policies and enriching the material in Ecotoxicology and Environmental Science courses, the author is interested in conducting research on the heavy metal content of Cd in Tilapia (*O. mossambicus*) from Taliwang swamp Lake, West Sumbawa Regency.

The author's observations suggest that the water body in TSL receives water flow from the surrounding area, which passes through agricultural areas. Farmers consistently use fertilizers, herbicides, fungicides, insecticides, and fertilizers in their agricultural activities. The presence of agricultural activities around the lake and the flow of water through the artisanal mining processing area opens up the possibility that the water body in TSL may be subjected to pollution. Heavy metals can accumulate in the water and on the bottom of the water, follow the food chain, enter the fish's body and tissues, and then accumulate. Therefore, various studies have been conducted to analyze the heavy metal content in fish tissue. This study attempts to analyze the Cd metal content in Tilapia (*Oreochromis mossambicus*) originating from Taliwang Swamp Lake.

Research Methods

This research was conducted from March to June 2025. This research was conducted in Taliwang Swamp Lake. Two research stations were taken, namely the eastern and western stations of the lake. The determination of the station is based on the existence of the lake's topography.

Data collection method

The sampling technique used in this study was purposive sampling. The reason for using purposive sampling is that not all samples have criteria that match the study's characteristics. The criteria in these samples are the length 15 – 20 cm and weight 150-250 g/fish of the Tilapia. Then the samples of this fish were analyses in the West Nusa Tenggara Health, Testing and Calibration Laboratory Center.

Data Analysis Method

The analysis process begins by taking fish muscle tissue as the part to be tested [26]. Wet samples were weighed as much as 0.5 g. Furthermore, Cd content analysis was carried out using Atomic Absorption Spectrophotometry (AAS), wet destruction stage on sample destruction is the process of degradation of organic material in samples by utilizing strong acidic liquids, namely HNO_3, as a destructive agent [27]. The steps in sample destruction are carried out by; inserting 0.5 gr of sample into a Kjeldahl flask, then adding 1 gr of catalyst, namely a solution of Na_2SO_4 and $CuSO_4$ with a ratio of 2: 1, followed by adding 6 mL of H2SO4 as a solvent, then heated for 2-3 hours at a temperature of 350ºC until the solution becomes clear, and then cooled. To determine the concentration of Cadmium, it is measured using atomic absorption spectrophotometry (AAS). The data obtained is in the form of Cd heavy metal content in ppm (parts per million). The next stage involves processing the Cd concentration obtained descriptively, and then the data are displayed in table form according to the AAS results.

Results and Discussion

The analysis of cadmium (Cd) content in Tilapia (*O. mossambicus*) from Taliwang Swamp Lake from two research locations is presented as follows:

Table 1. Laboratory analysis results of Cadmium (Cd) content in tilapia (*O. mossambicus*) tissue from Taliwang Swamp Lake

No	Fish Spesies	Sample location / Treatment	Cd content (ppm)
1	Tilapia	A. West side	
		Location 1 (1)	0.03
		Location 1 (2)	0.03
2.	Tilapia	B. East side	
		Location 2 (1)	0.03
		Location 2 (2)	0.03

Source: Laboratory analysis results from West Nusa Tenggara Health, Testing and Calibration Laboratory Center

Based on laboratory analysis, the cadmium (Cd) content in tilapia fish from TSL, West Sumbawa Regency, was 0.03 mg/kg. Tilapia fish typically live in swamps and lakes, then can serve as bioindicators in their natural habitat [28]. This Cd content is still below the threshold limit stipulated by the Food and Drug Monitoring Agency (BPOM) Regulation Number 9 of 2022 concerning Requirements for Heavy Metal Contamination in Processed Foods, which is 0.3 mg/kg (ppm) for processed fish products.

The concentration of cadmium (Cd) found in tilapia fish from Rawa Taliwang Lake, West Sumbawa Regency, indicates that the waters of TSL have been contaminated by Cd. This Cd is suspected to originate from agricultural activities, as the study site is located in an area surrounded by rice fields. The source of this Cd is attributed to the use of fertilizers by farmers. Phosphate fertilizer also contains Cd [3; 29]. If humans consume tilapia containing Cd, the copper can accumulate in the body, which is dangerous because it can damage bone tissue. Research data indicate that the Cd content is still relatively low, so tilapia from TSL, West Sumbawa Regency, remains safe for consumption. Consuming tilapia can cause negative impacts that could affect human health in the future.

Accumulation of heavy metals can occur in the bodies of fish such as betta fish, snakehead fish, and tilapia fish. The results of research [30] reported that the content of heavy metals in fish from the Saguling reservoir was as follows: Cd, 1.89 - 66.57 ppb; Cu, 0.29-247.40 ppb; and Pb, 1.60-40.32 ppb. The results of this study reinforce the findings, particularly for the heavy metal Cadmium (Cd). It was also reported that Tilapia fish contained heavy metals Pb at a level of 0.48 mg/ kg and Hg at 1.26 mg/kg. Research also shows that carnivorous fish contain higher levels of heavy metals than omnivorous and herbivorous fish [31]. Meanwhile, Cd has also been found in pomfret at levels of less than 1 mg/kg [21].

Tilapia fish are organisms that can accumulate heavy metals in their bodies due to environmental factors, such as increased temperatures. Rising water temperatures lead to increased accumulation of heavy metals in the fish's body. The accumulation and toxicity of heavy metals are influenced by rising water temperatures. Temperature can directly affect fish metabolism [2]. Heavy metals that accumulate due to increased temperature include cadmium (Cd) and mercury (Hg).

Snakehead fish, snakehead fish, eels, and tilapia can be exposed to the heavy metals Cd, Hg, and Pb. Fish exposed to heavy metals, such as cadmium (Cd), tend to accumulate more at temperatures above 30°C compared to room temperature. Increasing water temperature can increase the metabolic rate of aquatic organisms, such as Tilapia [7; 8; 33].

Fish living in freshwater have been shown to accumulate heavy metals. Research [34] showed that the average Pb content in milkfish (*Chanos chanos* Forsk.) samples was 0.0392 mg/kg, and the average Cu content was 0.0882 mg/kg. The Cu metal content in Rejung fish (*Sillago sihama*) was found to be 2.24 mg/kg [35]. Other research has concluded that milkfish contain a high level of cadmium [36].

Cd metal can affect bone tissue health in humans. If humans frequently consume fish contaminated with the heavy metal Cd, it can endanger their health. Excessive Cd metal content can have negative impacts on humans and other animals due to the nature of heavy metals that can damage bone tissue and easily accumulate in body tissues and organs [12, 24]. The occurrence of environmental changes can also have a significant impact on phytoplankton, such as algae and other plant species, because algae, like plants, are organisms that respond rapidly to changes in their surroundings. Plants are more sensitive to environmental changes than animals and humans [37].

Heavy metals are non-degradable by living organisms in the environment, which is the main factor contributing to their harmful effects on various organisms. As a result, these metals accumulate in the environment and settle at the bottom of the waters, forming complex compounds with organic and inorganic materials. These heavy metals can be taken up by algae, eaten by small fish and shrimp, and then enter the food chain [25].

Heavy metals are consistently found in various sediments. These metals can be taken up by phytoplankton, which feed on fish and shrimp. These heavy metals can originate from agricultural activities and are carried through rivers. Furthermore, various types of heavy metals can dissolve in river water, be adsorbed by fine particles (suspended solids) and carried to estuaries by the water in the river body. At river estuaries, river water and tidal currents can meet, allowing fine particles containing heavy metals to settle in the estuary. This can result in higher accumulations of heavy metals in estuarine sediments compared to those in the open sea. In general, river estuaries undergo a sedimentation process, where metals that are difficult to dissolve undergo a dilution process in the water column, then descend to the bottom of the water and settle in the sediment, resulting in sediment that always contains heavy metals [2; 24].

Aquatic environments are often contaminated with heavy metals, such as in Kendari Bay [6]. Community and industrial activities as sources of water pollution require attention to reduce the amount of waste entering the waters, thereby reducing their impact on organisms [38]. This study found that Cd levels have been detected in fish tissue.

Cadmium can accumulate in animals through the food chain, ultimately reaching humans [25]. Cadmium (Cd) is a metal that can be carried by water from sources of contamination, such as agricultural activities that use fertilizers. The Cd concentration in ricefield eels is suspected to originate from Cd contamination from agricultural areas around Lake Rawa Taliwang. Cadmium is readily absorbed by organic matter in the soil and becomes highly dangerous if the cadmium in the soil is absorbed through food. This can occur because soil containing cadmium (Cd) is absorbed by plants and subsequently consumed by herbivores that depend on these plants [13]. The cadmium (Cd) content found in the tissues of milkfish, tilapia, and snakehead fish was also reported by [3]. Cadmium (Cd) levels in climbing perch and snakehead fish in Taliwang Swamp Lake ranged from 0.011 ppm to 0.016 ppm.

Sources of heavy metal pollution, such as Cd, in plants can come from fertilizers, pesticides, irrigation water, or even the surrounding air [39]. Many organic (synthetic) fertilizers still contain the heavy metal cadmium (Cd). Although the amounts are small, if the soil is regularly fertilized with Cd, it can accumulate and be absorbed by vegetables growing in local agricultural lands. Similarly, cadmium can accumulate in various aquatic organisms, including squid, fish, oysters, and shrimp. Sensitivity to cadmium can vary significantly among aquatic organisms. Organisms living in saltwater are known to be more resistant to cadmium poisoning than those living in freshwater.

Several studies have shown that cadmium (Cd) is found in water bodies and sediments. The Cd content found in the Cisadane River is <0.001 ppm. Heavy metal levels in the sediment of several locations that have not been polluted have been reported to have Cd content in the range of 0.020-0.070 ppm [40].

At certain concentrations, cadmium (Cd) can kill sperm cells in men. This is the basis for the belief that exposure to cadmium (Cd) vapors can lead to impotence. Cadmium's toxicity also affects the bones, kidneys, lungs, reproductive system, and organs [10].

Cd can also be carried in various waste streams. For example, industrial wastewater and used lubricating oil containing Cd can be carried into marine waters, as well as residues from fuel combustion that are released into the atmosphere and subsequently fall into the ocean. Cd levels in unpolluted seawater are less than 1 mg/L or less than 1 mg/kg of marine sediment (1 ppm). Several records indicate that cadmium (Cd) has been used in various industries, including dyeing and lubricating oil production. The cadmium content in super phosphate fertilizer can reach 170 ppm, fuel and lubricating oil contain Cd up to 0.5 ppm, and coal contains Cd up to 2 ppm [39].

Cadmium (Cd), as a heavy metal, can be harmful to the human body because it accumulates in the body through contaminated food and drink. Low seawater temperatures prevent cadmium from melting, but rather retain its intact molecules and sinks, mixing with the mud on the seabed. Cd can enter water bodies due to the discharge of sediment and waste containing Cd into the environment. Cd-contaminated rivers overflow, inundating areas such as bays and rice paddies, and the element is absorbed by plants, including mangroves and other nearby vegetation.

Cd poisoning has been reported in Japan, causing lumbago, a disease that progresses to bone damage, softening and cracking. The organs most affected by Cd poisoning are the kidneys and liver. Concentrations of 200 μg Cd/gram (wet weight) in the renal cortex can lead to kidney failure and death. The accumulation of Cd in the body increases with age, namely, the half-life in the body is around 20-30 years [15].

Cadmium absorbed by the human body through food can be excreted through feces, but a small portion enters the kidneys and is excreted through urine. The heavy metal cadmium (Cd) can accumulate in the kidneys along with proteins, disrupting enzyme activity. Consuming foods containing cadmium (Cd) over a long period of time can result in chronic poisoning. Symptoms will appear over time and become chronic, such as kidney nephron poisoning, known as nephrotoxicity. Another impact of chronic cadmium (Cd) poisoning is that it can cause cardiovascular disorders, namely circulatory failure, characterized by decreased blood pressure or increased blood pressure (hypertension). Accumulation in the body occurs primarily in the liver and kidneys. The effects of acute poisoning include gastrointestinal disorders. Chronic effects, after long-term exposure to cadmium, primarily include impaired kidney function [10].

Water and sediment can be contaminated by heavy metals, such as the results of research by [15], which showed that the concentration of heavy metals in seawater at the mouth of the Cisadane River in July 2005 ranged between Lead $\leq$ 0.001- 0.005 ppm, and Cadmium $\leq$ 0.001-0.001

ppm. The concentration of heavy metals, like Pb and Cd, in seawater at the mouth of the Cisadane River was quite high in July 2005. The concentration of Pb metal was higher than other metals, followed by other heavy metals such as Cadmium (Cd).

Conclusion

From the previous description and discussion, the conclusion of this study is that the heavy metal Cadmium (Cd) content in Tilapia (*Oreochromis mossambicus*) from Taliwang Swimp Lake is 0.03 mg/kg or 0.03 ppm. This result is below the threshold set by the Indonesian Food and Drug Supervisory Agency number 9 of 2022, which is 0.3 ppm, so tilapia fish is still safe for public consumption.

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