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Analysis of Heavy Metal Lead (Pb) Concentration in Sedati Ponds and its Effect On Milkfish (*Chanos chanos*)

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Abstract
Heavy metal pollution, particularly lead (Pb), poses a serious threat to aquatic ecosystems and human health through bioaccumulation in fish. This study evaluates the quality of pond water used for milkfish (*Chanos chanos*) farming, measures Pb accumulation in milkfish, and examines the correlation between Pb concentrations in pond water and fish. Samples were taken from three stations in Tambak Cemandi Village, with water quality assessed through physical and chemical parameters and Pb concentrations analyzed using Atomic Absorption Spectrophotometry (AAS). The results indicate that parameters of pond water in Sedati was within safe limits and did not exhibit pollution. Pb concentrations in small, medium, and large milkfish were 0.0615 mg/kg, 0.0941 mg/kg, and 0.1522 mg/kg, respectively, supporting the bloaccumulation theory in fish. Food safety assessments show that small and medium milkfish are safe for consumption regarding Pb content. Pearson's correlation (r = 0.937) indicates a strong positive relationship between Pb levels in pond water and its concentration in milkfish, affirming that Pb exposure in water greatly affects Pb accumulation in fish. This study underscores the need for action taken regarding Pb contamination for the protection of the aquaculture environment. as well as safety of the food supply.

Keywords: pollution; pond water; lead; milk fish

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INTRODUCTION

According to Widiyanti *et al,*. (2022), the Sedati River is around 2.4 kilometers long and has an average width of 5 meters. It is of great importance for the fishery sector, especially in fostering aquaculture development. It serves as the primary water source for the surrounding pond areas, making the river's estuary a hub for local aquaculture practices, including fish farming, shrimp cultivation, and salt production. As noted by the Sidoarjo Regency Marine and Fisheries Office in the year 2020, 90% of the ponds in the area still practiced traditional cultivation, with the Sedati River serving as the primary irrigation source. River water quality directly impacts the condition of the ponds, and in turn, the river water quality impacts the health and optimal growth of the aquatic organisms cultivated.

In Indonesia, heavy metal contamination is one of the most concerning issues in an aquatiq ecosystem (Rahmadani & Diniariwisan, 2023). Water toxicants like lead (Pb), mercury (Hg), cadmium (Cd), and arsenic (As) heavily influence the quality of water and ecosystems' equilibrium. The Ministry of Environment and Marine Affairs (2020) reports that Indonesia's water bodies suffer heavy metal contamination in excess of 59 percent. This is attributed to industrial and mining activities along with the disposal of household wastes. Such extensive pollution endangers the marine biodiversity, threatens the survival of aquatic species, and poses considerable health risks to the sufferer and the community which rely on such water bodies (Darza, 2020). Sedati River and its neighboring water bodies suffer the same fate due to industrial and residential activities. In addition, pollution from both aerial and waterborne transportation systems, coupled with poor waste management, exacerbates the environments accumulation of lead (Pb). Elevated concentrations of heavy metals not only deteriorate the quality of water and aquatic life, and can also pose considerable risks to man for years to come.

Lead (Pb) is one of the most toxic heavy metals because of the impact it has on living organisms. In people, chronic exposure to Pb is capable of causing neurological, renal, and reproductive disorders (Hanifah *et al*., 2019). Exposed to lead, most aquatic species undergo severe physiological changes which impact their growth, reproduction, and general behavior (Pratiwi, 2020). Elevated concentrations of Pb within water bodies can result in the destruction of tissues, reduction of immune functions, and in severe cases of death in fish and other aquatic life (Madusari *et al*., 2016).

Investigations in various places have shown that metals like lead (Pb) can bioaccumulate in fish and therefore pose a health hazard upon consumption. Research in Pekelongan has found that milkfish (*Chanos chanos*) has Pb concentration of 0.015 to 0.02 mg/kg which is still lower than the contamination limit set by SNI 78 87 of 2009 (Madusari *et al*., 2016). On the other hand, studies conducted in the Brantas river in East Java found that Pb concentration in tilapia (*Oreochromis niloticus*) was 0.05 mg/kg which is higher than the WHO permissible limit of 0.03 mg/kg (Sari & Prasetyo, 2018). These results reflect the far-reaching consequences of heavy metal pollution. In addition to the disruption of balance in aquatic habitats, fish caught from polluted rivers expose terrible health risks to humans. Because of these risks, it is important to further evaluate Pb contamination in water from Sedati ponds to assess its safety and, in turn, to guarantee that milkfish (*Chanos chanos*) would be safe for human consumption.

This study aims to assess the water quality parameters with a specific focus on the lead (Pb) contamination level in milkfish (*Chanos chanos*) ponds, both in the pond water and in the fish itself, as well as to determine the relationship between the Pb level in the water and in the fish. The results of the study are expected to throw light on the status of environmental contamination, the associated risks of consuming fish from these ponds, and the approaches that need to be adopted with respect to environmental surveillance in aquaculture.

MATERIALS AND METHODS

This research is descriptive research with observational methods. This study was conducted over one month, starting in October 2024. The sampling of pond water and milkfish (*Chanos chanos*) took place in the Sedati ponds, Sidoarjo. Sampling locations were determined using the purposive sampling method, which selects locations based on research objectives and specific considerations (Figure 1). The final selection resulted in three sampling stations: Station 1, a milkfish pond near Juanda Airport; Station 2, a pond adjacent to residential areas; and Station 3, a pond near mangrove/hilir zones. Sampling of milkfish and pond water was conducted at the selected stations. At each station, three milkfish of different sizes were collected: small (<25 cm) aged 3-5 months, medium (25-30 cm) aged 6-8 months, and large (>30 cm) aged over 9 months, sampled during the harvest period. Additionally, 600 mL of pond water was collected from each station. The water and fish samples were then analyzed for lead (Pb) concentration at the Ecology Laboratory of the Biology Department, Faculty of Mathematics and Natural Sciences, Universitas Negeri Surabaya.

Water quality measurements were conducted using physical and chemical parameters. Physical parameters included temperature measurement with a thermometer, turbidity assessment using a turbidimeter, and salinity measurement with a refractometer. Chemical parameters involved pH measurement using a pH meter and dissolved oxygen (DO) analysis using a DO meter. Water quality testing was performed in situ. Lead (Pb) concentration in river water and milkfish (*Chanos chanos*) was measured using the Atomic Absorption Spectrophotometry (AAS) method, following SNI 6989.6:2009.

The measurement data of lead (Pb) concentration in river water and milkfish (*Chanos chanos*) were analyzed by comparing them to established quality standards. Supporting water quality parameters, including temperature, pH, salinity, dissolved oxygen (DO), and turbidity, were assessed through descriptive quantitative analysis compared to regulations from the Ministry of Environment No. 51 of 2004 and Government Regulation No. 22 of 2021. The test results for lead (Pb) concentrations in pond water and overall water quality were compared with water quality standards outlined in Government Regulation No. 82 of 2001. Meanwhile, lead (Pb) concentration in milkfish (*Chanos chanos*) was evaluated against the quality standards set by the Decree of the Directorate General of Drug and Food Supervision, Ministry of Health No: 03725/B/SK/VII/89. Kruskal wallis test and Pearson correlation test was conducted using IBM SPSS Statistics 26 software to analyze the relationship between lead (Pb) levels in water and those found in milkfish (*Chanos chanos*).

RESULTS

The measurement of physical and chemical environmental parameters in the waters of Sedati fish ponds, including temperature, pH, DO, salinity, turbidity is presented in (Table 1).

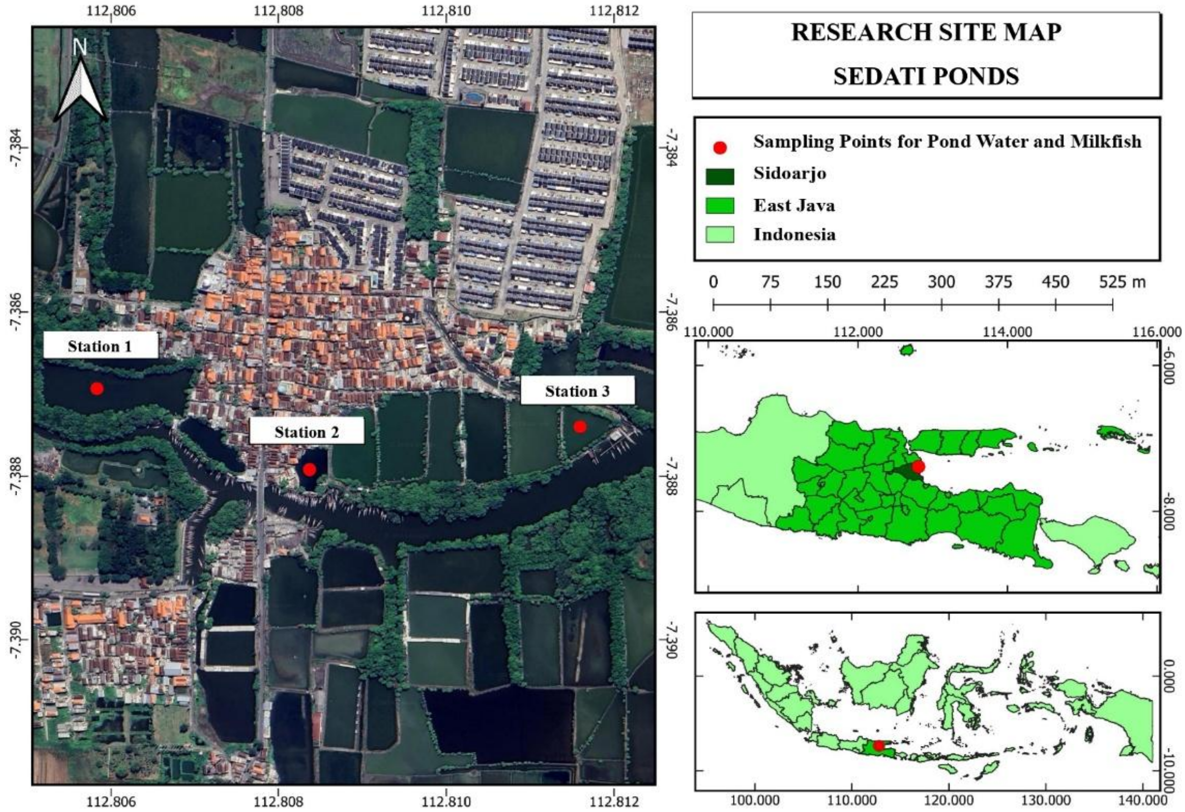

Figure 1. Research site map.

Table 1. Physical and chemical parameters of Sedati pond waters

Parameters	Station			Mean	Quality Standard
	1	2	3		
Temperature (°C)	31.25 ± 0.03	31.05 ± 0.07	30.93 ± 0.01	31.07 ± 0.16	-
pH	7.63 ± 0.00	7.42 ± 0.08	7.22 ± 0.02	7.42 ± 0.20	6.50- 8.50*
DO (mg/L)	4.74 ± 0.10	5.48 ± 0.54	7.09 ± 0.85	5.77 ± 1.20	≥5 mg/L**
Salinity (ppt)	9.68 ± 0.02	9.66 ± 0.01	9.68 ± 0.01	9.67 ± 0.01	10 - 25 ppt
Turbidity (NTU)	38.13 ± 1.86	38.57 ± 0.06	16.57 ± 0.06	31.09 ± 12.58	≤5 NTU**

*Government Regulation (PP) Number 22 of 2021
** Decree of the Minister of Environment Number 51 Year 2004

Based on the measurement of the temperature obtained, the highest of the temperature parameter was at station 1 at 31,25 ± 0,03°C; this indicates that the temperature in the waters of Sedati fish ponds had exceeded the allowable threshold, According to the Decree of the Minister of Environment No. 51 of 2004, temperature changes should not be more than ± 3 ° C from natural conditions in pond. The highest pH parameter is at station 1 valued at 7,63 ± 0. This indicates that the pH of the water was in a safe condition and in accordance with the standard. The highest DO parameter was at station 3 value at 7,09 ± 0,85 mg/L. The DO quality standard for pond waters is a minimum of 5 mg/L, this indicated that the dissolved oxygen content in the pond water did not meet the standards needed to support the life of aquatic organisms optimally. The highest salinity parameter was at station 3 at 9,68 ± 0,01 ppt. Based on general standards for pond waters that are not specifically regulated in national regulations, the ideal salinity for milkfish (*Chanos chanos*) cultivation usually ranges from 10 to 35 ppt (Samataring *et al*., 2020). The average salinity was slightly below the ideal range for milkfish farming commonly 10 to 35 ppt. This suggests that the salinity might be slightly low for optimization of milkfish farming. The hightes turbidy parameter is at station 2 value at 38,57 ± 0,06. The average turbidity far exceded the maximum limit set (5 NTU). This indicated that the waters are very turbid and do not meet the quality standard.

The results of lead (Pb) heavy metal concentration testing in the Sedati pond waters in Sidoarjo across three stations with are as follows (Table 2).

Table 2. Levels of Lead (Pb) in Pond Water

Stations	Pb Level (mg/L)	Mean Level of Pb (mg/L)	Quality Standard (mg/L)	Sig.
1	0.022	0.025 ± 0.013	0.100*	0.083
2	0.013			
3	0.039			

* Decree of the Minister of Environment Number 51 Year 2004

According to Minister of Environment Decree No. 51 of 2004, the maximum allowable Pb concentration in seawater is 0.1 mg/L. The average Pb concentration in Sedati pond waters was 0.0245 ± 0.0074mg/L, indicating that the Pb levels comply with quality standards and do not pollute the waters. The results of the Friedman test indicate that Pb concentrations in the water at the three stations did not differ significantly (p = 0.083).

The results of testing for lead (Pb) heavy metal concentrations in milkfish (*Chanos chanos*) of varying sizes from Sedati ponds in Sidoarjo, across three stations are as follows (Table 3). The data was obtained by measuring Pb concentrations in milkfish across specific periods. According to the Decree of the Directorate General of Drug and Food Supervision No. 03725/B/SK/VII/1989, the maximum allowable Pb concentration in food is 0.1 mg/Kg. The highest Pb concentrations was found in station 3, which exceeded the maximum limit of 0.1 mg/Kg. By fish size only large milkfish showed Pb concentrations significantly surpassing the established safety threshold. Based on the Kruskal-Wallis statistical test, the result p = 0.027 (<0.05) indicates a significant difference in Pb concentration across different fish sizes.

Table 3. Levels of Lead (Pb) in Milk Fish (*Chanos-Chanos*)

Fish Types	Levels of Lead (mg/Kg)			Mean (per fish type)	Quality Standard (mg/L)*	Sig.
	Station 1	Station 2	Station 3			
Small	0,009	0,026	0,077	0,061 ± 0,029	0.100	0.027
Medium	0,097	0,087	0,097	0,097 ± 0,005		
Large	0,142	0,131	0,182	0,152 ± 0.026		
Mean (per station)	0,106±0,032	0,081±0,052	0,119±0,055			

* Decree of the Director General of Food and Drug Control No. 03725/B/SK/VII/1989

The Pearson corelation test of lead metal content (Pb) in milkfish (*Chanos-chanos*) and water of the Sedati Pond is presented in Table 4. The Pearson correlation test results between lead (Pb) concentrations in Sedati pond water and Pb concentrations in milkfish (*Chanos chanos*) indicate a correlation coefficient of 0.937, This indicated a strong positive correlation. As Pb levels in the water increase, Pb concentrations in milkfish tended to rise. This demonstrated that an increase in Pb concentration in pond water was closely related to an increase in Pb concentration within the milkfish living in the ponds.

Table 4. Pearson Correlation Statistical Test for Pb Mrtal Content in Sedati Pond Water and Milk Fish.

Stations	Pond Water	Pb Level Milk Fish	Pearson Correlation Index
1	0,022	0,106	0,937
2	0,013	0,081	
3	0,039	0,119	

DISCUSSION

Water quality is primarily assessed using physical, chemical, and biological parameters, each of which plays a crucial role in maintaining a balanced aquatic environment. Physical factors, such as temperature and turbidity, directly influence habitat conditions and the overall health of aquatic organisms. Chemical properties, including pH levels, dissolved oxygen (DO), and salinity, regulate essential environmental conditions necessary for sustaining aquatic life. Furthermore, the incidence of metals, especially lead (Pb), have highly toxic and detrimental effects on aquatic life and humans necessitates monitoring (WHO, 2024).

The evaluated fishpond in Sedati had an average water temperature of 31.07 ± 0.16°C. Referring to Ministerial Decree No. 51 of 2004 concerning Natural and Controlled Water Temperature, The temperature is allowed to fluctuate within ±3°C from the baseline temperature of 28°C, thus being 25°C to 31°C. The sediment pond fish temperature is 31°C slightly surpassing the upper threshold. Considerably high water temperatures negatively impact the Aquaculture and fisheries ecosystems in many ways. Oxygen solubility and the ability to sustain life is reduced (Bok *et al*., 2023), the metabolic activity of fishes and other life forms which relies on energy, growth, and sustenance is elevated necessitating grater energy resources (Karim *et al*., 2023), Increased chances of disease occurrence owing to heightened pathogen activity (Smith *et al*., 2022), and thermal pressure which may influence fish reproductive cycles (Putra *et al*., 2023). The above described conditions necessitate risk management strategies. One such strategy is to install circulation water systems to stabilize the environmental conditions and promote sustainable aquaculture. It is equally important to provide shade by vegetation and optimizing other water circulation systems to control temperature and stabilize environmental conditions.

The mean pH of Sedati fish ponds was 7.42 ± 0.20 which was taken from daily monitoring through a certain timeframe. With reference to PP No. 22 of 2021, pH 6.5-8.5 is acceptable for water quality, therefore the pH of the ponds is still safe. Adhering to this range prevents the water from being too acidic or too alkaline, which mitigates a wide variety of physiological stress and health complications fish may experience. pH is vital for the growth of beneficial microorganisms which improves water quality, fish health, and controls the growth of harmful microorganisms, thus decreasing the likelihood of disease outbreaks in aquatic organisms (Yusoff *et al*., 2024).

The regulations concerning the Dissolved Oxygen (DO) quality standards and its minimum requirements for oxygen to support aquatic life were issued by the environment minister and government regulations. A DO concentration of 5 mg/L is the bare minimum for fish and other aquatic life to be healthy and to continue surviving. Examination of the waters in Sedati fish ponds showed an average DO of 5.77 mg/L. This is indicative of the water not containing adequate oxygen required to support healthy aquatic ecosystems. Prolonged exposure to the DO levels present in the Sedati fish ponds may result in oxygen-related physiological stress to fish and other aquatic organisms which may impact their growth, metabolism, and overall survival (Pane *et al*., 2023). The installation of aeration systems, improvement in water circulation, and vegetation management are oxygenation strategies which could be implemented to help stabilize DO levels and optimize conditions for aquatic life in Sedati fish ponds. In addition, the sustainable practices in aquaculture need to be supported by thorough regular monitoring.

Low levels of dissolved oxygen (DO) in water can lead to hypoxic conditions which may cause significant stress, hinder growth, and increase fish mortality (Scabra *et al*., 2022). Hypoxia, or low oxygen levels, for protracted durations can disrupt metabolic activities and slow down physiological functions which may impact life sustaining processes. Oxygen deficient conditions for fish over a long duration pose great health threats such as respiratory arrest and population-wide death (Humairah *et al*., 2024). Increasing oxygen levels in water bodies and creating a stable environment for organisms to flourish can be achieved through enhanced aeration, optimized water circulation, and better vegetation to some extent, which reduces the impact of hypoxia.

The average reported salinity of Sedati fish ponds is 9.67 ± 0.01 ppt, which is lower than the recommended range of 10-35 ppt for *Chanos chanos* farming ponds (Samataring *et al*. 2020). While the aquaculture industry is not governed by specific legal salinity requirements for pond waters, such waters should not exceed optimum levels for the healthy growth, strong immune response, and high yield of the system (Lusianto *et al*., 2019). Milkfish are prone to stress when salinity levels dip under the recommended range. Such stress can slow down growth, weaken resistance to diseases, and make the fish more vulnerable overall (Putri *et al*., 2023). Milkfish are classified as euryhaline, which means they are capable of adapting to different salinity levels. However, long-term exposure to suboptimal levels is harmful to their welfare and physiological functions (Lustianto *et al*., 2020). Decreases beyond 10 ppt may impair metabolic functions and perturb the osmoregulatory balance, making fish vulnerable to environmental stress (Cahyani *et al*., 2023). Controlled water exchange, addition of required minerals, better pond management, and other such measures can be incorporated to create stable optimal conditions for farming milkfish.

Average turbidity value in Sedati fish ponds reached 31.09 ± 12.58 NTU, which is far higher than the allowed threshold of 5 NTU set in the Decree of the Minister of Environment No. 51 Tahun 2004. It shows that the turbidity of the fish ponds is too high and the water is too dirty. This increase in turbidity is harmful to phytoplankton, and thus, the food chain in the pond (Nuriya *et al*., 2010). Decreased photosynthetic activity results in low oxygen levels which is important for fish. Moreover, fish living in turbid waters will undergo many physiological stresses which weak their immune system, decrease their appetite, and slow their growing rate (Lustianto *et al*., 2020). Moreover, the suspended particles of turbid water may accumulate on fish gills interfer, impairing oxygen intake. Under such prolonged exposure, they could develop lethal breathing troubles and higher death rate (Indrayani *et al*., 2014). Effective water management methods in the ponds is essential to eliminate turbid water and improve the fish pond oxygen levels.

Examining the Sedati Sidoarjo ponds for the presence of the heavy metal lead (Pb) revealed an average concentration of 0.024 ± 0.007 mg/L, sampled at three locations/stations . Based on the Decree of the Minister of Environment No. 51 Year 2004, the maximum permissible Pb concentration in water is 0.1 mg/L. This indicates that the concentration of lead in the water still fulfilled the quality standards. Low lead concentrations in Sedati fish pond waters can have impact on milkfish (*Chanos-chanos*) so as to minimize the cause of poisoning or accumulation of heavy metals in the body of milkfish (*Chanos-chanos*). This condition supports the survival of fish and other aquatic organisms in the pond, as well as ensuring safe fishery products for consumption (Yusoff *et al*., 2024).

The test results showed that the concentration of lead (Pb) in milkfish (*Chanos-chanos*) in fish ponds Sedati Sidoarjo exceededs the maximum limit set, at 0.1 mg/Kg. Station 1 showed Pb concentration at 0,106 ± 0,032 mg/Kg, station 2 at 0,081 ± 0,052 mg/Kg, and station 3 at 0,119 ± 0,055 mg/Kg. Based on these data, the Pb level at stations 1 and 3 were above the safety threshold and indicated Pb contamination in the milkfish, risking poisoning and physiological disorders.

Based on the size of milkfish, the results of heavy metal lead (Pb) levels of milkfish (*Chanos-chanos*) of small size (<25 cm) or aged 3-5 months at three stations get an average of 0,0615 ± 0,0299 mg/Kg, medium size (25-30 cm) or aged 6-8 months get an average of 0,097 ± 0,005 mg/Kg, large size (>30 cm) or aged more than 9 months get an average of 0,152 ± 0.026 mg/Kg. According to the Decree of the Director General of Food and Drug Control No. 03725/B/SK/VII/1989, the maximum concentration of lead in food is 0.1 mg/kg. These results indicate that milkfish (*Chanos-chanos*) with a large size (<25 cm) accumulate heavy metal lead (Pb) more than other fish sizes so that they get high lead heavy metal bioaccumulation effects and are not suitable for consumption. Bioaccumulation theory explains that fish can absorb and store lead from their environment faster than they can remove it, thus increasing lead levels in the body (Triastuti *et al*., 2016).

Correlation of Pb level in water and fish indicated a moderate positive relationship. As Pb levels in the water increase, Pb concentrations in milkfish also tend to rise, but this relationship is still close to perfect and is still influenced by other factors. However despite the occurrence of bioaccumulation processes, the measured Pb levels in milkfish tissues generally remain below the maximum thresholds established by both national and international food safety standards. At certain locations the Pb values approach or exceed these limits, it indicates a potential health risk for consumers who regularly consume fish. The data indicate that various environmental factors play a critical role in determining the Pb concentration in aquaculture waters. Variability among sampling stations reflects differences in the physical and chemical characteristics of the water, which can influence the extent of heavy metal bioaccumulation in aquatic organisms (Handayani, 2020). Research done in the fish ponds of Semarang revealed that the milkfish had the highest Pb concentration of 0.34 mg/kg which exceeds the safety limits (Hartati, 2017). The Pb levels in Sedati ponds, however, seemed to exhibit a lower concentration suggesting perhaps, Sedati's environmental conditions are better managed or influenced by different pollution sources. Another research supporting Pb bioaccumulation in milkfish in Buntung River waters showed the bioaccumulation mechanism works reliably, although the Pb concentration in fish tissues differs regionally based on pollution levels (Sari & Prasetyo, 2018). This comparison highlights that, even if the aquaculture sites are different, the processes of bioaccumulation are similar, the concentration of Pb in fish tissues depend mainly on the environmental conditions.

These results contribute significantly for devising policies for water quality management in aquaculture ponds. Continuous monitoring of Pb concentrations is necessary to determine and manage the sources of pollution, and in comparison with other studies, further highlights the necessity of managing water in reference to a specific area in order to safeguard aquaculture products (Prasetyo, 2021).

CONCLUSION

Based on the results of research and data analysis, it can be concluded that the status of Sedati pond water quality in terms of physical parameters, chemistry is in a safe/unpolluted status, while based on heavy metal parameters lead has an average of 0.024 mg/L which means it still meets the quality standards and does not pollute the environment. The average levels of heavy metal lead (Pb) in small, medium, and large milkfish (*Chanos-chanos*) at the three stations were 0.0615 mg/Kg, 0.0941 mg/Kg, 0.1522 mg/Kg respectively. There was a positive correlation of lead levels in water and in milkfish (*Chanos chanos*), indicating a bioaccumulative effect of Pb in the Sedati milk fish.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest with respect to the research, authorship, and/or publication of this article. All results presented in this study are solely the product of objective research, and no financial or personal relationships have influenced the findings.

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