Jurnal Ilmiah
SAMUDRA AKUATIKA
Volume 9 (1) Juni 2025: 27-37

e-ISSN: 2614-6738
p-ISSN: 2621-5314
DOI: 10.33059/jisa.v9i1.11525

The effects of Increasing Detergent Concentration on Water Quality and Behavioral Responses of Nile Tilapia (*Oreochromis niloticus*)

Dampak Peningkatan Konsentrasi Deterjen terhadap Kualitas Air dan Respons Perilaku Ikan Nila (Oreochromis niloticus)

Helmy Akbar[1,✉], Bagus A. Utomo[1], Muhammad Isnan Zuhri[1], Wiwid Arif Pambudi[1], Esraa E. Ammar[2], Hefni Effendi[1]

[1]Environmental Research Center, IPB University, Bogor, Indonesia
[2]Lecture of Plant Ecology, Botany Department, Faculty of Science, Tanta University, Egypt
✉Email: helmy.akbar@apps.ipb.ac.id

Abstrak: The increased use of detergents during the COVID-19 pandemic has raised concerns regarding their impact on aquatic environments, particularly water quality and aquatic biota. Even prior to the pandemic, the effects of detergent exposure on water quality and aquatic organisms had been studied, but the surge in hand soap and cleaning product usage has likely led to higher concentrations of Linear Alkylbenzene Sulphonate (LAS), a common active ingredient. This study aimed to determine the median lethal concentration (LC50) of detergent compounds, observe behavioral changes in *Oreochromis niloticus* (Nile tilapia), and examine histopathological damage to gill tissues following exposure. The LC50 value was determined to be 0.061 mg/L, with an effective concentration range between 0.059 mg/L and 0.063 mg/L. Behavioral responses observed in exposed fish included disorientation, reduced responsiveness, and lethargic movements. Histological analysis revealed significant damage to the gill tissue in exposed specimens compared to the control group. These findings indicate that increased detergent concentrations in aquatic environments may pose a significant threat to fish health and overall ecosystem stability.

Keywords: **detergent, fish behavior, fish physiology, LC50, *Oreochromis niloticus*, water pollution**

Abstract: *Peningkatan penggunaan deterjen selama pandemi COVID-19 menimbulkan kekhawatiran terhadap dampaknya pada lingkungan perairan, khususnya kualitas air dan biota akuatik. Bahkan sebelum pandemi, pengaruh paparan deterjen terhadap kualitas air dan organisme akuatik telah banyak diteliti. Namun, lonjakan penggunaan sabun cuci tangan dan produk pembersih lainnya diperkirakan meningkatkan konsentrasi Linear Alkylbenzene Sulphonate (LAS) sebagai bahan aktif utama di perairan. Penelitian ini bertujuan untuk menentukan nilai LC50 dari bahan deterjen, mengamati perubahan perilaku pada Oreochromis niloticus (ikan nila), serta mengkaji kerusakan histopatologis pada jaringan insang setelah terpapar. Nilai LC50 diperoleh sebesar 0,061 mg/L dengan rentang konsentrasi efektif antara 0,059 mg/L hingga 0,063 mg/L. Respons perilaku yang diamati pada ikan yang terpapar meliputi disorientasi gerak, penurunan respons terhadap rangsangan, serta gerakan yang cenderung pasif. Analisis histologis menunjukkan adanya kerusakan signifikan pada jaringan insang ikan uji dibandingkan dengan kelompok kontrol. Temuan ini mengindikasikan bahwa peningkatan konsentrasi deterjen di lingkungan perairan berpotensi membahayakan kesehatan ikan dan kestabilan ekosistem secara keseluruhan.*

Kata kunci: deterjen, perilaku ikan, fisiologi ikan, LC50, Oreochromis niloticus, pencemaran air

I. INTRODUCTION

At the end of 2019, the world was shocked by the emergence of infection in the lungs, and the cause was identified as the coronavirus (Covid-19). Coronavirus infection has rapidly spread worldwide, and to date, more than 20 million people have been infected [1, 2]. This condition makes WHO, as the world health agency, declare the status of Covid-19 as a pandemic. Early January was the beginning of the entry of Covid-19 into Indonesia [3].

This pandemic has made WHO recommend health protocols such as washing hands regularly with soap and running water, using hand sanitizers in daily activities, and immediately washing

clothes used after traveling to ensure the transmission of viruses attached to clothes can be prevented (Przekwas & Chen, 2020). The consequence that must be accepted with this condition is the increased use of chemicals such as detergents, liquid soap, and hand sanitizers (Ankit *et al*., 2021; Chirani *et al*., 2021; Usman, Farooq, & Hanna, 2020). The increasing use of these chemicals will undoubtedly increase the pollutant burden on water and soil (Ammendolia *et al*., 2021). Based on the information obtained, the increase in the use of these chemicals reached 300%. In this case, detergent waste is gray water (non-toilet) from households (domestic wastewater).

The entry of detergent contamination into the waters will affect the ecology of the waters, both from aquatic biota's life and water quality (Sobrino-Figueroa, 2018; Perry *et al*., 1984; Holt, 2000). This research is a simulation to see detergent contamination that affects water quality and aquatic life (laboratory scale). The results of this study are expected to be one of the reference materials used by stakeholders to monitor and issue regulations and appeals regarding the use of detergents during the Covid-19 pandemic.

The effect of detergents on water biota has been tested in several previous studies with several types of detergents (Sobrino-Figueroa, 2018; Pettersson *et al*., 2000; Ezemonye *et al*., 2009). Some of the biotas that have been tested include crustacean species such as shrimp and fish groups. The results showed that water biota exposed to detergents damaged body organs (histopathological changes), growth disturbances, changes in behavior, and killed the water biota tested. The study of the effect of detergent surfactants on the life of tiger prawns post larvae (Penaeus monodon Fabr) showed a decrease in growth rate in post-larvae of tiger prawns during sub-chronic tests along with increasing concentrations. The surfactant toxicity to juvenile tiger prawns increased with increasing concentration and exposure time (Supriyono *et al*., 2008).

The acute toxicities of two types of local detergents were compared using Clarias gariepinus (Burchell, 1822) and Heterobranchus longifilis Valenciennes, 1840 hybrid (Heteroclarias) seeds. In a 96-hour bioassay test with increased concentrations of toxicants, increased respiratory distress, loss of balance, lethargy, and sudden fish mortality were observed in exposed fish. There is a solid concentration-mortality relationship for toxicity, resulting in a strong positive correlation coefficient for each type of detergent. This study concluded that the waste containing this detergent should not be carelessly disposed of in water to avoid harming fish and other aquatic life (Ndome *et al*., 2013). The use of test biota for shrimp and fish larvae is based on the sensitivity of the two biotas, which naturally occur inland waters. This study will obtain the concentration of toxins (detergents) that cause death in aquatic organisms, which will be tested using the LC50-96-hour value approach with the bioassay method. The target area is the aquatic ecosystem in general, considering that pollution in public waters such as rivers is alarming. The river is used as a garbage disposal channel, one of which is domestic wastewater.

This LC50 study was carried out on a laboratory scale to test the effect of pollutants in detergents on the types of fish that became animals in this study. This research is an initial description to see the response of biota in the aquatic environment, especially in stagnant waters. As an illustration, the Bogor areas (West Java) have a relatively high population density as a buffer zone for Jakarta (The capital of Indonesia). At this time, hand sanitizers, hand soap, and detergent groups are often applied to office areas, public facilities, restaurants/restaurants, and malls. There is a tendency to use materials such as hand soap and other types of detergents increased during the COVID-19 pandemic. The beneficiaries of this research are the

community, researchers, and stakeholders (policymakers). The research area is carried out in Bogor City and or Bogor Regency on a laboratory scale in the PPLH IPB laboratory.

II. METODE

This research was conducted using experimental methods on the laboratory scale at the Environmental Research Center (PPLH), IPB University. The activity in the toxicity test was divided into three stages, i.e., the acclimatization stage, preliminary examination, and the primary test. The study was conducted following a U.S. toxicity test procedure (US EPA 1996).

Before testing, the test biota was acclimatized for four days. It is intended that the test animals adapt to different environmental conditions from the original requirements and avoid parasitic and bacterial infections in the test animals. The test animals were acclimatized in an aquarium measuring 100×50×30 cm. At the acclimatization stage, the test animal mortality should not be more than 10% (Jacobs & Franson, 1995). This is based on the requirements of the test animals in good health.

The preliminary test is carried out to determine the waste concentration interval used as a contaminant in the primary test. The test animals used in the preliminary test were 10 in each aquarium, measuring 30×30×30 cm. The preliminary test determined the upper threshold (N) and the lower concentration (n). The upper threshold concentration (N) is the lowest concentration of the toxicant that causes all test animals to die at the exposure time of 24 hours, while the lower threshold concentration (n) is the highest concentration of the toxicant that does not cause death in the test animals at the exposure time of 24 hours.

The experiment was a short-term bioassay using a static type test (US EPA 1991). The concentration consisted of five waste concentration treatments and one treatment as control with three replications. The concentration of waste used in the main experiment comes from the results of preliminary experiments.

The tools and materials used are a set of aquarium installations, fish juvenile (test biota), toxic materials (detergents), and supporting laboratory equipment. The water quality parameters analyzed included phosphate, dissolved oxygen, pH, temperature, COD, and MBAS (surfactant). In addition, physiological observations of the test biota were also carried out during the exposure time. Estimation of the LC50 value is by using the probit method. The probit method is a parametric statistical procedure at a 95% confidence interval. In addition, a descriptive analysis of the data from laboratory analysis was also carried out to see changes in water quality on the behavior of the test biota.

III. RESULT AND DISCUSSION

Before conducting the research, a preliminary test was conducted to determine the range of doses used in the LC 50 test. The concentration used refers to the previous study by Megawati *et al*., 2015. The preliminary test results showed that the mortality ratio reached 45% at a concentration of 61.04 mg/l of the toxicant and the mortality ratio reached 100% at 81.04 mg/l. Using the formula from USEPA (2002), five concentrations of the experimental toxicity test were obtained, namely P1: 47 mg/L, P2: 53 mg/L, P3: 61 mg/L, P4: 71 mg/L, P5: 81 mg/L.

In the probit analysis carried out to determine the LC50 value, it was found that the concentration that was effective in responding to mortality in the test biota of tilapia fish was 61 mg/l with an effective concentration range of 59 mg/l to 63 mg/l (results of determining the LC50 value with complete probit analysis can be seen in Figure 1a). When the primary test was carried out, the mortality rate was 100% at 96 hours, obtained at P4: 71 mg/L and P5: 81 mg/L (Figure 1b).

Water quality monitoring was also carried out during the study, namely

temperature and dissolved oxygen (DO). Temperature measurements at the test concentrations of the P4 and P5 treatments were only carried out for 12 hours because all of the test animals died at 12 hours. The temperature range in the control aquarium ranged from 24.8 ºC to 27.1 ºC, treatment P1 24.6 ºC to 27.0 ºC, treatment P2 25.0 ºC to 27.1 ºC, P3 treatment 24.5 ºC to 26.9 ºC, P4 treatment 24.4 ºC to 27.3 ºC, and P5 treatment ranged from 24.5 ºC to 27.1 ºC detailed temperature ranges for the five treatments and controls (Figure 2a).

From measurements of dissolved oxygen content carried out in control and treatment aquariums, the oxygen content in control aquariums ranged from 5.3 mg/l to 6.8 mg/l, and P1 ranged from 4.4 mg/l to 7.4 mg/l, P2 went from 4.3 mg/l to 7.2 mg/l, P3 went from 4.1 to 6.9 mg/l, P4 went from 5.8 mg/l to 7.0 mg/l, P5 ranged from between 5.6 mg/l to 7.1 mg/l details of the range of dissolved oxygen content in experimental aquariums in control and treatment can be seen in Figure 2b.

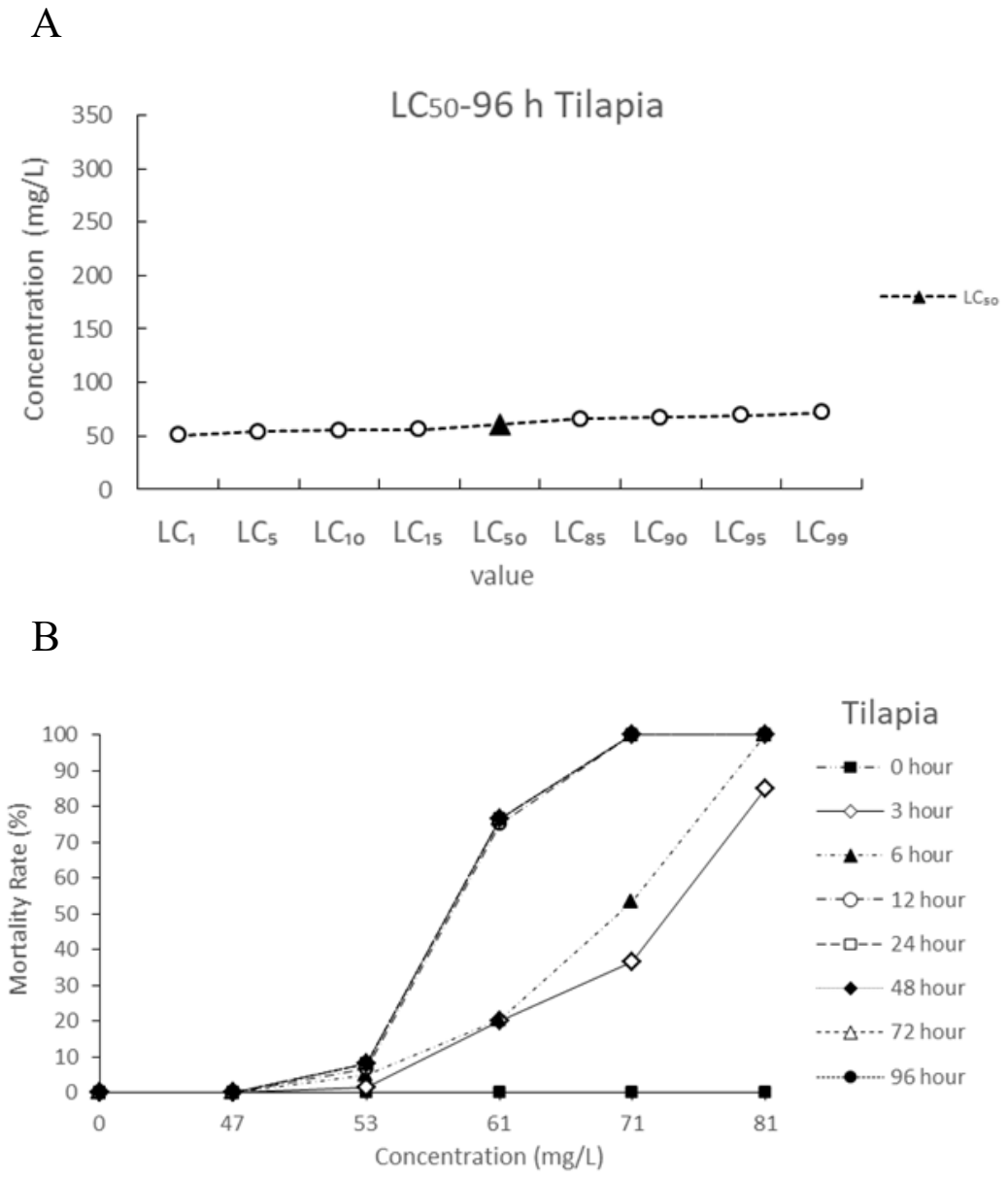


Figure 1. Lethal Concentration at 96-hour (a), percentage of mortality rate (b).

In the study, the degree of acidity (pH) of water was also measured in this study where the level of acidity (pH) in control ranged from 6.6 to 6.9, P1 between 6.6 to 6.9, P2 ranged from 6.5 to 6. ,9, P3 from 6.6 to 6.9, P4 from 6.7 to 6.9, P5 from 6.8 to 6.9. The pH values obtained were not significantly different in all treatments based on the results obtained. The detailed observation time of pH conditions at the time of observation can be seen in Figure 2c. According to references from previous studies, detergent materials such as linear alkylbenzene sulphonate (LAS) exist. No effect on ammonia, temperature, and pH (Uedeme-Naa & Gabriel, 2017). Previous experiment in *C. gariepinus* exposed to Akee apple and sausage plant extract also shows the same condition (Onusiriuka & Ufodike, 1994). However, there are behavioral changes in fish seen in this study.

Fish behavior change

At the 0th hour of observation, when the toxicant was first introduced, the fish movements still looked normal, and the fish spread on all sides of the water in the aquarium. This was observed at both the lowest and highest concentrations. At the 3rd hour observation, behavior was changed in the 3, 4, and 5 treatment aquariums (P3, P4, and P5). The fish did not move and gathered at the bottom of the aquarium. Also seen in the movement of fish that experience disorientation. Fish response at P3 still responds to vibrations and sounds from the aquarium. Likewise, aquariums with treatments 4 and 5 (P4 and P5).

At the 6th hour of observation, the fish in the P5 aquarium, the mortality rate had reached 100%, so further behavior remarks were not observed. In the treatment of aquariums P1 and P2, the fish movement was evenly distributed in all water columns, and none experienced movement disorientation. The fish were on the bottom of the aquarium in the P3 and P4 treatments. The responsiveness of the fish to disturbances in the form of vibration and sound was very low, and some fish experienced disorientation in movement.

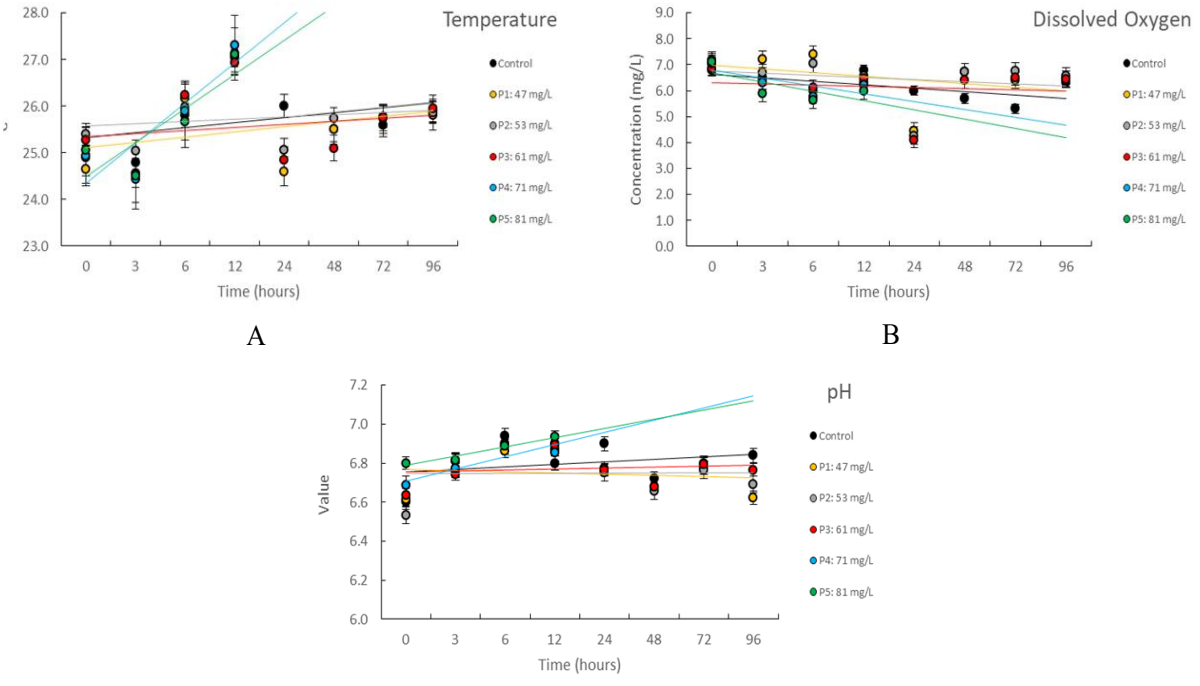


Figure 2. Condition and fluctuations of temperature (a), dissolved oxygen (b), and pH (c) during LC50 observations on control and treatment for up to 96 hours.

During the 12th hour observation, the P1 aquarium observed fish on all sides of the aquarium, the responsiveness of movement to disturbances in the form of vibrations and normal sounds. In the P2 treatment, the fish were at the bottom of the aquarium with poor responsiveness, and some fish experienced disorientation in motion. In the 3rd aquarium, the fish were at the bottom of the aquarium with poor responsiveness, followed by motion disorientation in some observed fish. In the 4th treatment aquarium (P4), all fish experienced death observed at the 12th hour. At the 12th hour observation, the mortality rate reached 75% in the 3rd aquarium treatment (P3).

Observations at 24 hours, in treatment 1, fish occupy positions in the entire water column. Fish movements are still normal, and fish are still responding to sounds and vibrations made on the aquarium walls. In the aquarium with treatment 2 (P2), the fish were at the bottom of the aquarium with less active movements. In the treatment in aquarium 3 (P3), the fish were on the bottom side of the aquarium with minimal response to vibration and sound.

At 48, 72, and 96 hours of observation, fish in aquariums 1 and 2 positioned the fish occupying the entire water column with normal responses and active movements. In the treatment aquarium 3 (P3), the fish's position occupied the whole water column with less activity and poor response in some fish. At the end of the observation, the fish experienced 8% mortality in the 2nd aquarium (P2), while in the 1st aquarium (P1) and controlled; there was no mortality percentage from the animals tested. At the end of the observation, it was found that the total rate of mortality in aquarium 3 (P3) reached 77%.

According to Sharma & Rani (2016), no adverse behavioral changes or mortality were recorded in the control experiment throughout the bioassay. While the fishes treated with detergent have several abnormal behavioral responses like incessant jumping, gulping for air, frequent surface-to-bottom movement, restlessness condition, sudden change of direction during movement, loss of equilibrium, and resting at the bottom and hence gradually onset of inactivity. Feeding was also reduced in the fish present under surfactant's influence. Further, the toxicity of detergent increased with increased concentration.

The effect of physiological respiration on the breathing rate was also affected in fish in surfactant mixed water. When these fishes were introduced into water containing surfactant, they immediately showed discomfort and began to rush and faster operculum movements initially. The fishes show normal Physiological respiration in the control group, while the fishes of the first group (6.63 mg/l) show increases in oxygen consumption on the first day. While on the rest of the days, i.e., the second, third, and fourth day, there was a reduction in gills operculum movements 67, 47, and 24, respectively. Further, like the first group, fishes in the second group (with 13.3 mg/l detergents) also showed the same trend of oxygen consumption (Sharma & Rani, 2016).

Detergents disrupt the nervous structure of fish by plummeting the activity of enzymes at nicotinic and musculanic receptors (Megawati *et al*., 2015). Dropping the activity of these enzymes allows a protracted effect of acetylcholine, a neurotransmitter, on the receptors. The disabling of enzymes can have a toxic impact leading to harmful physiological effects or even fatality at specific concentrations. Detergent surfactants restrain acetylcholine esterase in the brain of *Clarias gariepinus* (Burchell, 1822) (Setac, 1997) and also 80% inhibition in the neural tissue of *Coptodon guineensis* (Günther, 1862) (reported as *Tilapia guineensis*) following the acute effect of detergent Ezemonye *et al*., 2015).

Morphology of fish gill

Detergents disrupt fish's nervous structure by plummeting the activity of enzymes at nicotinic and musculanic

receptors (Uedeme-Naa & Gabriel, 2017). Dropping the activity of these enzymes allows a protracted effect of acetylcholine, a neurotransmitter, on the receptors. The disabling of enzymes can have a toxic impact leading to harmful physiological effects or even fatality at specific concentrations. Zaccone *et al.* (1985) evaluated the poisonous impact of ionic active detergent LAS on fish for some days and observed a decrease in the activity of the enzymes in the plasma (Zaccone *et al*., 1985). In this study, the actions of AST and ALT increased significantly in the gill, which indicated cellular toxicity of the detergent even at low doses under a prolonged period of exposure. Another study shows the activity levels of AST, ALT, and total adenosine triphosphate (ATPase) in muscles, gills, liver, and brain of *Oreochromis mossambicus* (Peters, 1852) (reported as *T. mossambica*) exposed to detergent, indicated transaminases were elevated in all the tissues in addition to a shift in aminotransferases reaction under the impact of surfactants (Priya *et al*., 2016).

This study has also seen the condition of the gills and lamella gills that suffered damage. There occurs loss of nervous control and fishes along the lateral side of the body. The body was slimy due to mucus secretion from the epithelium of the gills. Even at a low concentration, fishes die due to bleeding through the gills with both detergent powders; in observing some gill preparations of tilapia fish, the process of atropy and hypertrophy occurs in the lamella gills in toxicity testing for 96 hours. Other processes such as necrosis and the process of fat degradation were not seen in the observations this time. On more extended observations, it was found that a chronic sub concentration of 0.042 mg/l C_{12}LAS causes necrosis at the opposite end of the Kuruma shrimp's (*Penaeus japonic*us) gills on the observation of the 14th day, and most cases of atropy in the gill filaments of Kuruma shrimp at acute concentrations of 0.75 mg/l C_{12}LAS were obtained at the observation of the 96th hour (Supriyono *et al*., 2008). This is seen in the image of gill conditions and gill lamella (Figure 3).

The ability of detergent surfactants to interact with proteins and impair the permeability of cell membranes is suspected to be the cause of organ tissue damage in fish (Partearroyo *et al.,* 1991; Otzen, 2017). There are several similarities with post-larval tissue damage of penaeid shrimp due to exposure to LAS-type detergent surfactants (linear alkylbenzene sulphonate). Previously observations on some shrimp organ preparations found atropy, hypertrophy, necrosis, and fatty degeneration (Supriyono *et al*., 1984). Damage to gills and hepatopancreas can disrupt shrimp's metabolic processes, leading to penaeid shrimp's disruption growth. These water-containing surfactants cause cell rupture and interact with proteins and semi-permeable membranes (Supriyono *et al*., 2008). Mortality can be caused by more than one factor, all of which are stimulated by gills damage (Heath, 2018). At low toxic concentrations, mortality can be caused by the action of the substance on functions other than gas exchange or osmoregulation.

Other studies reported an effect on external morphology 100% survival was recorded in all three groups in our experiment (Onusiriuka & Ufodike, 1994). But the fish body was worst affected by the presence of surfactant in water, as swelling on the lips and gill lamellae were recorded in fish exposed to a 6.63 mg/l concentration of surfactant. Further, damage to the caudal fin, scars on the anal fin, swelling in the eye region, and gill lamellae were observed in fish placed under 13.3 mg/l concentration of surfactant. Abel's research explained that the significant biochemical response to the effect of detergents in fishes is the inhibition of the activities of several enzymes such as AST, ALT, ACP, and ALP (Abel, 1974).

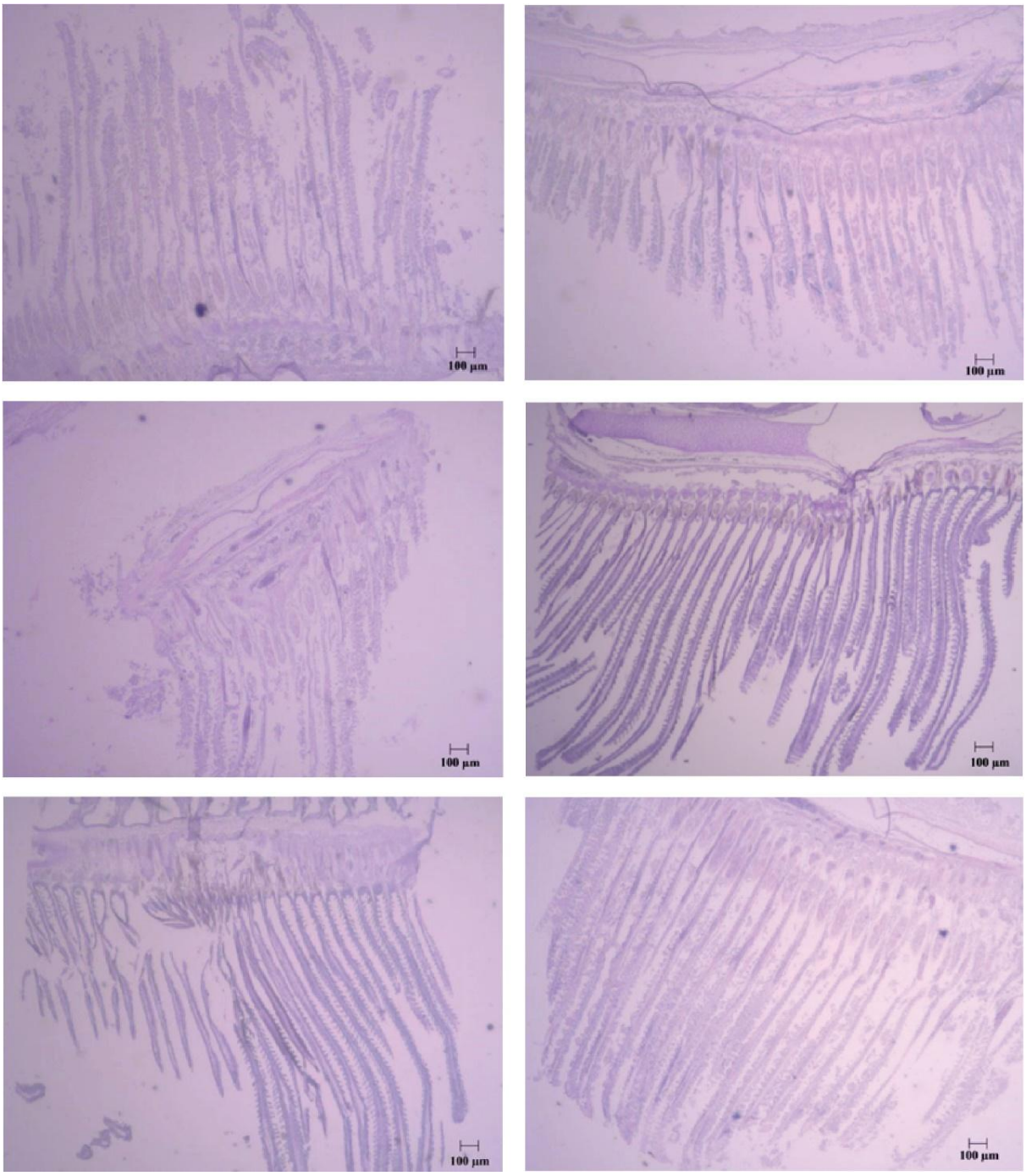


Figure 3. Condition of gill and lamellae gill of Tilapia fish.

Gills, a primary site of osmoregulation and respiration, may be highly vulnerable to lesions because they immediately contact aquatic toxicants. The most prominent manifestation of the acute toxicological effect of detergents is on the gill tissue of the fish. Destruction of the gill epithelium is regarded as a consequence of reducing surface tension by surfactants (Bock, 1965). Schooling patterns of fish were reviewed by Partridge (1982). Detergent causes impairment of chemoreceptor organs (Bardach & Holl, 1965). Operculum movement and schooling pattern was measured as an index for behavioral toxicity in control and detergent exposed fish fingerlings. Many of the available reports are related to surfactants' effects during an exposure period of 15 min to 30 days.

The effect of detergents on water biota has been tested in several previous studies with different types of detergents. Some successfully tested biotas include crustacean types such as shrimp and fish groups. In general, water biota exposed to detergents showed damage to organs (histopathological changes), growth disorders, behavioral changes, and caused mortality of biota. Studies of the influence of surfactant detergent (alkyl sulfate (AS)) on the post-larval life of Penaeid shrimp (*Penaeus monodon* Fabr.) showed a decrease in growth rate in post-larvae of Penaeid Shrimp at the time of chronic sub-test along with the increasing concentration of AS. During acute and sub-chronic toxicity tests, histopathological changes in shrimp gills and hepatopancreas were observed. Alkyl sulfate toxicity to Penaeid shrimp Juvenil increases with increasing concentration and exposure time (Supriyono *et al*., 2008)**.**

Studies of the increase in pollutants discharged into the waters sourced from detergent waste and their effect on water biota have also been tested on a laboratory scale using Guppy fish (*Poecilia reticulata*). The experiment was conducted in vitro to determine LC50 (120h) household detergent against guppy fish. Probit analysis results show that a dose of about 33.4 mg/L is a lethal dose that kills 50% of guppy fish in 120 hours, doses below 30 mg/L do not kill any fish, while doses above 30 mg/L kill all individuals within a few hours (Azevedo & Lopes, 2019). The Linear Alkyl Benzene Sulphonate (LAS) type tested has inhibited all enzymes in the organs examined except Alanine Aminotransferase (ALT) and Acid Phosphatase (ACP) on the display of 150 juvenile *C. gariepinus* fish (Udeme-naa & Gabriel, 2017).

In Nigeria, acute toxicity of two types of local detergents has been compared using catfish juvenile *Clarias gariepinus* ♀x *Heterobranchus longifilis* ♂hybrid (Heteroclarias) in bioassay for 96 hours with increased concentration of toxins increases the disturbance of the respiratory system, loss of balance, lethargy and sudden death of fish has been observed in exposed fish. There is a solid concentration-mortality relationship for toxics, resulting in a strong positive correlation coefficient for each type of detergent. The study results concluded that waste containing this detergent should not be disposed of carelessly in bodies of water to avoid harm to fish and other aquatic life (Ndome *et al*., 2013)**.**

IV. CONCLUSIONS

The concentration that effectively responded to mortality in the test biota of tilapia fish was 61 mg/l with an adequate concentration of 59 mg/l to 63 mg/l. In observing some gill preparations of tilapia fish found, the process of atropy and hypertrophy that occurs in the lamella gills in toxicity testing for 96 hours. At 48, 72, and 96 hours of observation, fish in aquariums 1 and 2 positioned the fish occupying the entire water column with normal responses and active movements. In the treatment aquarium 3 (P3), the fish's position occupied the whole water column with less activity and poor response in some fish. At the end of the observation, the fish experienced 8% mortality in the 2nd aquarium (P2), while in the 1st aquarium (P1) and controlled; there was no mortality percentage from the animals tested. Effect on Physiological Respiration The breathing rate was also affected in fishes present in surfactant mixed water.

V. ACKNOWLEDGMENTS

This research was supported by funding from The Osaka Gas Foundation of International Cultural Exchange (OGFICE) 2021.

REFERENCES

Abel, P. D. (1974). Toxicity of synthetic detergents to fish and aquatic invertebrates. *Journal of Fish Biology, 6*(3), 279–298.

Ammendolia, J., Saturno, J., Brooks, A. L., Jacobs, S., & Jambeck, J. R. (2021). An emerging source of plastic pollution: Environmental presence of plastic personal protective equipment (PPE) debris related to COVID-19 in a metropolitan city. *Environmental Pollution, 269*, 116160.

Ankit, Kumar, A., Jain, V., Deovanshi, A., Lepcha, A., Das, C., & Srivastava, S. (2021). Environmental impact of COVID-19 pandemic: More negatives than positives. *Environmental Sustainability, 4*(3), 447–454.

Azevedo, C., & Lopes, J. (2019). Lethal concentration (LC50) (120h) of neutral household detergent Limpol in guppy *Poecilia reticulata*. *Journal of Survey in Fisheries Sciences, 5*(2), 25–32.

Bardach, J. E., Fujiya, M., & Holl, A. (1965). Detergents: Effects on the chemical senses of the fish *Ictalurus natalis* (le Sueur). *Science, 148*(3677), 1605–1607.

Bock, K. J. (1965). Über die wirküng von waschrostoffen auf fische. *Archiv für Fischereiwissenschaft, 17*, 68–77.

Brüssow, H. (2020). Efforts towards a COVID-19 vaccine. *Environmental Microbiology, 22*(10), 4071–4084.

Chakraborty, I., & Maity, P. (2020). COVID-19 outbreak: Migration, effects on society, global environment and prevention. *Science of The Total Environment, 728*, 138882.

Chirani, M. R., Kowsari, E., Teymourian, T., & Ramakrishna, S. (2021). Environmental impact of increased soap consumption during COVID-19 pandemic: Biodegradable soap production and sustainable packaging. *Science of The Total Environment, 796*, 149013.

Ezemonye, L. I. N., Ogeleka, D. F., & Okieimen, F. E. (2009). Lethal toxicity of industrial detergent on bottom dwelling sentinels. *International Journal of Sediment Research, 24*(4), 479–483.

Ezemonye, L. I. N., Ozekeke, O., & Isioma, T. (2015). Distribution and ecological risk assessment of pesticide residues in surface water, sediment and fish from Ogbesse River, Edo State, Nigeria. *Journal of Environmental Chemistry and Ecotoxicology, 7*(3), 20–30.

Heath, A. G. (2018). *Water pollution and fish physiology*. CRC Press.

Holt, M. (2000). Sources of chemical contaminants and routes into the freshwater environment. *Food and Chemical Toxicology, 38*, S21–S27.

Jacobs, B. C., & Franson, J. D. (1995). Operational system for quantum cryptography. *Electronics Letters, 31*(3), 232–233.

Megawati, I. A., Zulfikar, A., & Melani, W. R. (2015). Uji toksisitas deterjen terhadap ikan nila (*Oreochromis niloticus*). Universitas Maritim Raja Ali Haji.

Ndome, C. B., Mowang, D. A., & Ayibaemi, T. T. (2013). Comparative acute toxicity of local detergents (Omo and Ariel) on fingerlings of the *Clarias gariepinus*♀ × *Heterobranchus longifilis*♂ hybrid. *AACL Bioflux, 6*(4), 415–422.

Olivia, S., Gibson, J., & Nasrudin, R. (2020). Indonesia in the time of Covid-19. *Bulletin of Indonesian Economic Studies, 56*(2), 143–174.

Onusiriuka, B. C., & Ufodike, E. B. C. (1994). Acute toxicity of water extracts of sausage plant *Kigelia africana* and akee apple *Blighia sapida* on African catfish, *Clarias gariepinus* (Teugals). *Journal of Aquatic Science, 9*, 35–41.

Otzen, D. E. (2017). Biosurfactants and surfactants interacting with membranes and proteins: Same but different? *Biochimica et Biophysica Acta (BBA) - Biomembranes, 1859*(4), 639–649.

Partearroyo, M. A., Pilling, S. J., & Jones, M. N. (1991). The lysis of isolated fish (*Oncorhynchus mykiss*) gill epithelial cells by surfactants. *Comparative Biochemistry and Physiology Part C:*

Comparative Pharmacology, 100(3), 381–384.

Partridge, B. L. (1982). The structure and function of fish schools. *Scientific American, 246*(6), 114–123.

Perry, R., Kirk, P. W. W., Stephenson, T., & Lester, J. N. (1984). Environmental aspects of the use of NTA as a detergent builder. *Water Research, 18*(3), 255–257.

Pettersson, A., Adamsson, M., & Dave, G. (2000). Toxicity and detoxification of Swedish detergents and softener products. *Chemosphere, 41*(10), 1611–1620.

Priya, R., Uma, T., Saravanan, N., & Jothi Narendiran, N. (2016). Efficacy of detergent on hepatocyte morphological changes in fish, *Tilapia mossambica*. *Journal of Entomology and Zoology Studies, 4*(5), 655–659.

Przekwas, A., & Chen, Z. (2020). Washing hands and the face may reduce COVID-19 infection. *Medical Hypotheses, 144*, 110261.

Setac. (1997). *Chemical ranking and scoring: Guidelines for developing and implementing tools for relative chemical assessments*. SETAC Press.

Sharma, R., & Rani, S. (2016). Effect of surfactant on external morphology and physiological respiration of freshwater fish, *Labeo rohita*. *CIBTech Journal of Zoology, 5*(3), 1–5.

Sobrino-Figueroa, A. (2018). Toxic effect of commercial detergents on organisms from different trophic levels. *Environmental Science and Pollution Research, 25*(14), 13283–13289.

Supriyono, E., Berlianti, & Nirmala, K. (2008). Studi mengenai toksisitas surfaktan deterjen, alkyl sulfate (AS), terhadap post larva udang windu *Penaeus monodon* Fabr. *Jurnal Ilmu-Ilmu Perairan dan Perikanan Indonesia, 15*(2), 141–147.

Supriyono, E., Takashima, F., & Strussmann, C. A. (1998). Toxicity of linear alkylbenzene sulphonate (LAS) to juvenile kuruma shrimp, *Penaeus japonicus*: A histopathological study on acute and sub-chronic levels. *Journal of the Tokyo University of Fisheries, 85*(1), 1–10.

Uedeme-Naa, B., & Gabriel, U. U. (2017). Plasma enzymes in the gill of *Clarias gariepinus* juvenile exposed to chronic levels of linear alkyl benzene sulphonate. *Applied Science Reports, 19*(3), 95–101.

Usman, M., Farooq, M., & Hanna, K. (2020). Environmental side effects of the injudicious use of antimicrobials in the era of COVID-19. *Science of The Total Environment, 745*, 141053.

Zaccone, G., Fasulo, S., Lo Cascio, P., & Licata, A. (1985). Patterns of enzyme activities in the gills of the catfish *Heteropneustes fossilis* (Bloch) exposed to the anionactive detergent Na-alkyl-benzenesulphonate (LAS). *Histochemistry, 82*(4), 341–346.