Hematological Response of Tilapia (Oreochromis niloticus) in Laundry Wastewater

SAPARUDDIN1*, YANTI1, SALIM1, HARISH MUHAMMAD2
1Department of Biology Education, Faculty of Teacher Training and Education, Sembilanbelas November Kolaka University
*Email: saparuddin.yadin@gmail.com
Jl. Pemuda No. 339 Kolaka, Southeast Sulawesi, Indonesia. 93518
2Leibniz-Institute of Freshwater Ecology and Inland Fisheries Müggelsedamm 310, 12587 Berlin, Germany

Received 7 March 2020; Received in revised form 30 April 2020; Accepted 17 May 2020; Available online 30 June 2020

ABSTRACT

The high concentration of detergent in the aquatic ecosystem potentially affects the fish's physiological condition by disrupting the respiration process and changing the concentration of blood components and chemistry. This study aimed to determine the condition of the hematological parameters of tilapia (Oreochromis niloticus) exposed to wastewater from the laundry industry. Each treatment was stocked with five fish per aquarium (50x30x30 cm). This study used a completely randomized design (CRD) technique with treatments include P0 (0%) as a control, P1 (1%), P2 (2%), P3 (3%), P4 (4%), and P5 (5%) with each treatment exposed to a specific concentration of wastewater and residues. The results showed that the hemoglobin levels of treatments decreased, with the lowest mean of hemoglobin level found in the P2 (7.05 gr%), and the lowest concentration on the 30th day was 7.11 gr%. There were no significant effects of wastewater on erythrocytes and leucocytes number among treatments (P > 0.05). While there were increasing hematocrit levels, the largest mean level was found in the P4 treatment with a value of 24.11 gr%, and the largest mean on the 20th day of observation showed a value of 23.51 gr%. Wastewater from the laundry industry can affect tilapia's hematological condition by decreasing the hemoglobin concentration and increasing the hematocrit levels above the normal condition.

Keywords: detergent; fish; hematology; laundry industry, wastewater

INTRODUCTION

Detergent is a type of water-soluble surfactant used to remove impurities from laundry in the household and laundry industries. The laundry industry's work process is simple and straightforward: to dissolve detergents in water because detergents have a better hardness than soap (Yuliani et al., 2015). Therefore, this industry will produce wastewater that contains detergents, which are discharged directly to the nearest aquatic environment. (Ardiyanto & Yuantari, 2016; Yusmidiarti, 2016).

Detergent addition from the laundry industry wastewater cause water quality reduction (Sumisha et al., 2015; Uzma et al., 2018). The negative effect of detergents deteriorates water quality due to their different chemical components (Giannorio et al., 2017; Goel & Kaur, 2020), led toxicity and genotoxic effects on aquatic life (Adewoye, 2010; Sobrino-Figueroa, 2013), and tend to be the most resilient to biodegradation (Hidaka et al., 2010; Verdia et al., 2016). Surfactant is one of the main ingredients of the detergent, causing foam in the water and creating a layer that inhibits the process of transferring oxygen from the air to water (Sugito et al., 2014; Srinet et al., 2017).

Fishes as bioindicator play a role in monitoring the effect of heavy metals contamination (Authman, 2015; Łuczyńska et al., 2018). Tilapia (Oreochromis sp.) used as biomarker to assess water pollution (Osman, 2012), bioaccumulation (Abdel-Baki et al., 2011; Eneji et al., 2011), and measure the risk of pollution to humans (Adel et al., 2016).

The accumulation of detergent from the laundry industry will cause a low supply of dissolved oxygen (DO) in the water. This condition will disrupt air-breathing fish (Lee et al., 2012; Franklin, 2014), reduce the energy as DO declined (Tran-Duy et al., 2012), and cause death for a longer period of time (Hobbs &
SAPARUDDIN et al.  

McDonald, 2010). Death can occur due to physiological deviations of blood components. Changes in blood components and blood chemistry, both qualitatively and quantitatively, can affect the fish's condition. Therefore, hematological conditions can be used as indicators to detect and determine a fish's health status (Sabilu, 2010).

Only a few research on the laundry industry's wastewater and residues affect Oreochromis niloticus hematological condition, so further studies are necessary. This research contribution is expected to provide effective strategies for controlling laundry wastewater's negative impact on the aquatic life and environment, mainly to fish.

MATERIALS AND METHODS

Tilapia were obtained from the Undulako Fish Seed Center, Kolak Regency, Southeast Sulawesi. This research was conducted by using a completely randomized design (CRD) method consisting of six treatments and three repetitions: P0 (0%), P1 (1%), P2 (2%), P3 (3%), P4 (4%) and P5 (5%) with each treatment exposed to a specific concentration of wastewater and residues from laundry industry.

Acclimatization and culture. Four months old tilapia (5±0.3 - 7±0.2 g, 7±0.4 - 9±0.1 cm) were acclimatized in two larger aquariums (100x80x80 cm) before stocked in the experimental aquarium (50x30x30 cm). After acclimatization, tilapia were weighed and measured. Tilapia were stocked to the 18 experimental aquariums with a stocking density of five fish. Continuous aeration was performed homogeneously to maintain a stable oxygen concentration in each tank (Siburian et al., 2019). A total of 5% of water volume was siphoned and exchanged daily to remove the uneaten feed and the fish feces. Tilapia culture was conducted for 30 days. The food used is a commercial tilapia feed with a protein content of 40% (Siburian et al., 2019). Tilapia was fed on a limited basis, twice a day, at 08.00 and 17.00 WITA. The feed is distributed evenly and is given up to 5% of tilapia weight per day.

Parameters. The parameters observed in this study include water quality, surfactant analysis of wastewater from the laundry industry, and hematological parameters. The water quality parameters consist of dissolved oxygen, temperature, and pH, measured every day during the study. The anionic surfactant test consists of a test tube filled with 10 ml of methylene blue solution, 5 ml of chloroform was added, and then 1% of the detergent solution was added and stirred, resulting in a color change. The cationic surfactant test included a test tube with 10 ml of 0.002% blue bromine phenol solution in Na acetate buffer pH 3.6-3.9, adding 1% of the detergent. It was stirred until distributed uniformly, and the color was observed. The blood was sampled through the caudal vein near the tail between tilapia scales. Blood samples are slowly suctioned up to 2 ml each tail, then transferred to a 4 ml vacuum tube that has been moistened with anticoagulation. The blood samples were taken on the first day as a control, then on the 10th, 20th, and 30th days. Hemoglobin concentration was measured by using the Sahli method. Total erythrocyte and total leukocyte were counted by using an improved Neubauer hemocytometer. The hematocrit measurement was conducted using microhematocrit tubes and then centrifuged at 1500 rpm.

Data analysis. The data obtained from the hematological observations of tilapia were analyzed using ANOVA and followed by the Duncan test using IBM SPSS version 23. Differences were considered as being significant at p < 0.05.

RESULT AND DISCUSSION

Water quality analysis. According to Table 1, it is shown that water quality parameters of control P0 have not changed from the beginning to the end of the experiment. There were some differences in water quality data between various concentration treatments. In general, DO values of treatments decreased during the 30 days of the study. In control P0, the DO value was quite stable from the beginning to the end of the study. In the treatment of P1, the DO value decreased, starting from day 10 to day 30. The pH value in P1 treatment has increased from day 10 to day 30. The other treatments of P2, P3, P4, and P5 showed a similar trend by decreasing the DO
concentrations and increasing the pH. In contrast, the temperature of all treatments during the investigation tends to be stable.

Table 1. Results of the analysis and measurement of water analysis

| Concentration | DO (mg/L) | Temp. (°C) | pH | DO (mg/L) | Temp. (°C) | pH | DO (mg/L) | Temp. (°C) | pH |
|---------------|-----------|------------|----|-----------|------------|----|-----------|------------|----|
| 0%           | Day 0: 6.6 | 26.7       | 7.1 | Day 10: 6.6 | 26.3       | 7.1 | Day 20: 6.6 | 26.8       | 7.7 | Day 30: 6.5 | 25.3       | 7.2 |
| 1%           | Day 0: 6.7 | 26.7       | 7.2 | Day 10: 6.4 | 26.5       | 7.4 | Day 20: 5.2 | 26.5       | 7.6 | Day 30: 4.3  | 23.4       | 7.8 |
| 2%           | Day 0: 6.9 | 26.4       | 7.2 | Day 10: 5.8 | 26.3       | 7.5 | Day 20: 4.7 | 27.1       | 8    | Day 30: 3.8  | 23.6       | 7.6 |
| 3%           | Day 0: 6.8 | 26.6       | 7.1 | Day 10: 6.1 | 26.5       | 7.5 | Day 20: 4.2 | 26.5       | 7.6 | Day 30: 3.6  | 24.8       | 8.3 |
| 4%           | Day 0: 6.7 | 26.5       | 7.1 | Day 10: 6.2 | 26.4       | 7.8 | Day 20: 4.4 | 25.6       | 8.3 | Day 30: 3.9  | 24.5       | 8.5 |
| 5%           | Day 0: 6.6 | 26.2       | 7.1 | Day 10: 5.8 | 25.7       | 7.4 | Day 20: 4.8 | 26.2       | 8.2 | Day 30: 3.7  | 25.1       | 8.3 |
| Average      | Day 0: 6.7 | 26.5       | 7.1 | Day 10: 6.2 | 26.3       | 7.5 | Day 20: 4.9 | 26.5       | 7.9 | Day 30: 4.3  | 24.1       | 8.0 |

This study indicates that wastewater treatment from the laundry industry reduces the water quality by lowering the DO value. The higher the concentration of treatment correlates to the lower DO value. Furthermore, the longer the duration of the study, the lower the DO value. These water quality parameters support the primary data on the hematological parameter condition of tilapia. These data were obtained from DO, pH, and temperature measurements during the study from the beginning to the end. According to table 1, it is shown that there is a decrease in DO in higher concentration. This is due to the effect of the laundry industry’s wastewater that causes a reduction in DO transfer, resulting in a decrease in the DO. The laundry industry wastewater contains detergents that accumulate the surfactants in surface and ground water (Ghose et al., 2009; Meffe & de Bustamante, 2014), causing problems in the sedimentation of water (Rebello et al., 2014; Hassan et al., 2017), and reducing the system free energy at higher concentration (Ivanković & Hrenović, 2010; Gao & Sharma, 2013). Besides, the phosphate from detergents in the upper part of the river can also stimulate aquatic macrophytes and float weeds growth (Rajan, 2015; Ramachandra et al., 2017). The abundant of aquatic plants will increase phosphorus decomposition, affect aeration and water quality (Rajan, 2015), and deficiency of DO levels (Patty et al., 2015). This adversely affects the physiological, biochemical, and ionregulatory responses of fish (Velisek et al., 201; Rajan, 2015). Water temperature during the study fluctuated during the study, except in control P0 at a concentration of 0%. An increase in water temperature also causes a reduction in DO levels in the water. The optimal temperature for tilapia growth is range 22-30°C (Zuhrawati, 2014; Nivelle et al., 2019). pH values of water at various treatments increase with the high detergent concentration due to bases chemical of detergent.

**Surfactant analysis of wastewater from laundry industry.** The anionic surfactant test showed a solid blue color in the chloroform layer, and the cationic surfactant test showed a natural blue color. This is consistent with Utomo et al. (2018), if the high anionic surfactant content will show blue indicator in the chloroform phase. Detergent solution in the first press laundry industry used in this study contained concentrated surfactants.

**Hemoglobin Concentration.** The results of the study show a decrease in hemoglobin levels in all treatments, except control P0, up to the 30th day of measurements. The treatments that have been exposed to the wastewater from the laundry industry have varied responses to the level of hemoglobin in each treatment. The lowest hemoglobin levels were found in treatments P2, P3, P5, P1, and P4 with an average of hemoglobin levels, respectively 7.05 gr%, 7.06 gr%, 8.79 gr%, 8.98 gr%, and 9.32 gr%, respectively (Figure 1). The P0 had quite a constant hemoglobin level (10.45 gr%) since beginning to the end of the experiment. Statistical analysis showed that hemoglobin levels of P2 was not significantly different from P3 (P > 0.05) but was significantly different to
the three other concentrations (P1, P3, P5) and control treatments (P < 0.05). The hemoglobin level of test fish in P5 was not significantly different from P1 and P4 (P > 0.05) but was significantly different from P2, P3 and control treatments. The P0 was significantly different from the other five treatments. This fact shows that waste from the laundry industry increases the accumulation of surfactants on the surface water that inhibits the transfer of oxygen to the fish, thus reducing the level of hemoglobin in tilapia blood under normal conditions (Saparuddin & Arbain, 2019).

![Graph showing hemoglobin levels](image1)

**Figure 1.** The average level of tilapia hemoglobin in P0 (0%), P1 (1%), P2 (2%), P3 (3%), P4 (4%) and P5 (5%)

The lowest hemoglobin level is in days 30, 20, 10, and 3, with the following percentage of 7.71 gr%, 7.80 gr%, 8.86 gr%, and 10.07 gr% (Figure 2). The hemoglobin level on day 30 did not differ with the hemoglobin level on day 20, but was different from the hemoglobin level on day 10 and 0 (p < 0.05). The hemoglobin level on day 20 was significantly different from the hemoglobin level on day 10 and day 0. Similarly, the hemoglobin level on day 10 was significantly different from the apparent rate of hemoglobin on day 0 (p < 0.05). While the level of hemoglobin on day 0 varies in real with all observed days. This indicates that time exposure to the laundry wastewater affects the level of hemoglobin tilapia. Low hemoglobin levels associated with the low active fishes (Satheeshkumar et al., 2012), affect oxygen carrying capacity of the blood (Atkins & Benfey, 2008), lower metabolic rate, and lower energy demand (Chapman et al., 2002).

![Graph showing concentration and hemoglobin](image2)

**Figure 2.** The average of tilapia hemoglobin levels under observation day 0, day 10th, day 20th and day 30th

**Number of Erythrocytes.** Figure 3 shows that the amount of tilapia’s erythrocytes is not subjected to significant quantity changes with detergent from the laundry industry. The highest erythrocytes number can be found in P1 (1.64 x 10^6 cells/mm³), followed by P4 (1.64 x
$10^6$ cells/mm$^3$), P3 ($1.53 \times 10^6$ cells/mm$^3$), P5 ($1.52 \times 10^6$ cells/mm$^3$), P2 ($1.51 \times 10^6$ cells/mm$^3$), and the smallest can be found in control P0 ($1.47 \times 10^6$ cells/mm$^3$).

Figure 3. The average number of tilapia erythrocyte in the treatment P0 (0%), P1 (1%), P2 (2%), P3 (3%), P4 (4%) and P5 (5%).

The erythrocytes number in tilapia among the treatment were not different ($p > 0.05$). The total amount of erythrocytes was not affected by any particular concentration of wastewater from the laundry industry. All treatments had average levels of erythrocytes' abundance. The erythrocytes concentration in studied fish were within the range $0.47-1.78 \times 10^6$/mm$^3$ described by Maftuch (2018), but was lower than those $1.13-1.31 \times 10^6$/mm$^3$ reported by Ismain & Mahboub (2016). The erythrocytes number still within range of health tilapia indicates the hematopoiesis process is still happening in tilapia even though it has been exposed to the laundry's wastewater industry.

Figure 4 shows the erythrocytes number at the lowest hemoglobin level at day 0, 30$^{th}$, 20$^{th}$, and 10$^{th}$ with a consecutive number of $1.46 \times 10^6$ cells/mm$^3$, $1.49 \times 10^6$ cells/mm$^3$, $1.52 \times 10^6$ cells/mm$^3$, and $1.65 \times 10^6$ cells/mm$^3$. The total number of tilapia erythrocytes linked with the wastewater from the laundry industry on day 0 did not actually differ with the erythrocytes number on the day 30$^{th}$ and the 20$^{th}$. However, it is different from the day 10$^{th}$. The erythrocytes number on day 30$^{th}$ was not significantly different from day 20$^{th}$ and day 10$^{th}$. It shows that the wastewater from the laundry industry did not affect the number of tilapia erythrocytes.

Figure 4. The average number of tilapia erythrocyte under observation on day 0, day 10$^{th}$, day 20$^{th}$, and day 30$^{th}$

**Number of Leukocytes.** Figure 5 shows that the tilapia leukocytes number is aligned with the waste detergent laundry and won't undergo significant quantity changes. The
SAPARUDDIN et al.

Biogenesis 74

The smallest leukocytes can be found in P2 \((10.25 \times 10^4 \text{ cells/mm}^3)\) followed by P3 \((11.00 \times 10^4 \text{ cells/mm}^3)\), P4 \((11.28 \times 10^4 \text{ cells/mm}^3)\), P5 \((11.39 \times 10^4 \text{ cells/mm}^3)\), while the highest leukocytes can be found in P0 \((11.39 \times 10^4 \text{ cells/mm}^3)\) and P1 \((11.39 \times 10^4 \text{ cells/mm}^3)\).

Figure 5. The average number of tilapia leukocytes in the treatment P0 (0%), P1 (1%), P2 (2%), P3 (3%), P4 (4%), and P5 (5%).

The lowest leukocytes number are found on day 20\(^{th}\), day 0, day 10\(^{th}\), and day 30\(^{th}\) with 10.91 \(\times 10^4\) cells/mm\(^3\), 11.04 \(\times 10^4\) cells/mm\(^3\), 11.07 \(\times 10^4\) cells/mm\(^3\), and 11.44 \(\times 10^4\) cells/mm\(^3\), respectively. The number of tilapia leukocytes lined with the waste laundry detergent from day 0 to day 30\(^{th}\) has no real difference. The leukocytes number in this study indicates that the hematotesis process continues to occur in tilapia even though it has been exposed to the waste detergent laundry. Several factors affect the number of leukocytes in fish, consisting of species (Sadauskas-Henrique et al., 2011; Seriani et al., 2013; Ribas et al., 2016), sex steroid (Milla et al., 2011; Krams et al., 2013; Chaves-Pozo et al., 2018), and lymphoid organs activity (Tort, 2011; Scapigliati, 2013). Leukocytes will decrease if the fish is in a response to stress, such as heat stress (Davis et al., 2008; Zafalon-Silva et al., 2017), while elevated leukocytes number due to the immune response of stress syndrome, inflammatory processes, and oxidative stress (Lazado et al., 2010; Tort, 2011; Nardocci et al., 2014).

Figure 6. The average number of tilapia leukocytes under observation on day 0, day 10\(^{th}\), day 20\(^{th}\), and day 30\(^{th}\).

**Hematocrit Level.** The results showed an increase in hematocrit levels across exposure to the laundry detergent treatment up to the day 30\(^{th}\). The lowest hematocrit level can be found in P0 (21.77%). The highest hematocrit level can be found in P4 (24.11%), followed by P5 23.64%, P2 (22.83%), P1 (21.77%)(Figure 7).
Figure 7. The average hematocrit value of tilapia in P0 (0%), P1 (1%), P2 (2%), P3 (3%), P4 (4%) and P5 (5%).

Figure 8 shows that the lowest hematocrit concentration on day 0, day 10, day 20, and day 30 are 21.58%, 22.96%, 23.31%, and 23.51%, respectively. The statistical analyses showed that tilapia hematocrit levels are aligned with the concentration of wastewater from the laundry industry from day 0 until day 30th, and there were no significant differences among treatments (p>0.05).

The higher concentration of the wastewater of the laundry correlates to a higher increase of the hematocrit level. The normal hematocrit range of tilapia is between 21.00%-22.67%, as reported by Richard et al., 2003; Aly et al., 2008; Giron-Perez et al., 2008; Yue & Zhou, 2008). The high value of hematocrit (above normal levels) indicates that the hematopoiesis process in tilapia began to be interrupted due to exposure from the laundry industry's wastewater. The calculation of the hematocrit value and hemoglobin level reflects the oxygen that carries the blood's carrying power. A low concentration of hematocrit can cause damage or defects in the osmoregulation process, while a high value indicates an increased demand for oxygen or hypo-osmotic conditions (Oğuz, 2015; Zainuddin et al., 2017). The contamination of the water by detergent residues affects the local ecosystem with stable properties in the sediments, ease of absorption, and accumulation in the body tissue of fish, relevant to human health implication.

CONCLUSION

Wastewater from the laundry detergent industry affects tilapia's hematological condition by decreasing the hemoglobin concentration and increasing hematocrit levels higher than the normal condition, while the number of erythrocytes and leukocytes are still in the normal level.
REFERENCES

Abdel-Baki AS, Dkhil MA, Al-Quraishy S. 2011. Bioaccumulation of some heavy metals in tilapia fish relevant to their concentration in water and sediment of Wadi Hanifah, Saudi Arabia. African Journal of Biotechnology. vol 10(13): 2541–2547.

Abdel-Khalek AA, Elhaddad E, Mandalou S, Marie MAS. 2016. Assessment of metal pollution around sabal drainage in River Nile and its impacts on bioaccumulation level, metals correlation and human risk hazard using Oreochromis niloticus as a bioindicator. Turkish Journal of Fisheries and Aquatic Sciences. vol 16(2): 227–239. doi: https://doi.org/10.4194/1303-2712-v16_2_02.

Adewoye SO. 2010. Effects of detergent effluent discharges on the aspect of water quality of Asa River, Ilorin, Nigeria. Agriculture and Biology Journal of North America. vol 1(4): 731–736.

Atkins ME, Benfey TJ. 2008. Effect of acclimation temperature on routine metabolic rate in triploid salmonids. Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology. vol 149(2): 157–161. doi: https://doi.org/10.1016/j.cbpa.2007.11.004.

Authman MM, Zaki MS, Khallaf EA, Abbas HH. 2015. Use of fish as bio-indicator of the effects of heavy metals pollution. Journal of Aquaculture Research & Development. vol 6(4): 1–13. doi: http://dx.doi.org/10.4172/2155-9546.1000328.

Chaves-Pozo E, García-Ayala A, Cabas I. 2018. Effects of sex steroids on fish leukocytes. Biology. vol 7(1): 1–21. doi: https://doi.org/10.3390/biology7010009.

Davis AK, Maney DL, Maers JC. 2008. The use of leukocyte profiles to measure stress in vertebrates: a review for ecologists. Methods in Ecology and Evolution. vol 9(6): 1556–1568. doi: https://doi.org/10.1111/2041-210X.13020.

Docan A, Dediu L, Cristea V. 2012. Effect of feeding with different dietary protein level on leukocytes population in juvenile Siberian sturgeon, Acipenser baeri. Brandt. Archiva Zootechnica. vol 15(4): 59–67.

Eneji IS, Sha’Ato R, Annune PA. 2011. Bioaccumulation of Heavy Metals in Fish (Tilapia zillii and Clarias gariepinus) Organs from River Benue, North-Central Nigeria. Pakistan Journal of Analytical & Environmental Chemistry. vol 12(1): 42–49.

Franke F, Rahn AK, Dittmar J, Erin,N, Rieger JK, Haase D, Samonte-Padilla IE, Lange J, Jakobsen PJ, Hermida M, Fernández C, Kurtz J, Bakker TCM, Reusch TBH, Kalbe M, Scharsack JP. 2014. In vitro leukocyte response of three-spined sticklebacks (Gasterosteus aculeatus) to helminth parasite antigens. Fish & Shellfish Immunology. vol 36(1): 130–140. doi: https://doi.org/10.1016/j/fsi.2013.10.019.

Franklin PA. 2014. Dissolved oxygen criteria for freshwater fish in New Zealand: a revised approach. New Zealand Journal of Marine and Freshwater Research. vol 48(1): 112–126. doi: https://doi.org/10.1080/00288330.2013.827123.

Gao B, Sharma MM. 2013. A family of alkyl sulfate gemini surfactants. 2. Water–oil interfacial tension reduction. Journal of Colloid and Interface Science. vol 407: 375–381. doi: https://doi.org/10.1016/j.jcis.2013.06.066.

Ghose NC, Saha D, Gupta A. 2009. Synthetic detergents (surfactants) and organochlorine pesticide signatures in surface water and groundwater of greater Kolkata, India. Journal of Water Resource Protection. vol 1(4): 290–298. Doi: https://doi.org/10.4236/jwarp.2009.14036.

Hassan FM, Al Obaidy AHMJ, Al-Ani RR. 2017. Detection of Detergents (Surfactants) in Tigris River-Baghdad/Iraq. International Journal of Environment & Water. vol 6(2): 1–15.

Hidaka H, Tamano T, Fujimoto T, Machinami T, Oyama T, Horiiuchi T, Serpone N. 2010. Binary cationic BDDAC/anionic DoS surfactant systems of variable compositions. mineralization by an advanced oxidation process in aqueous dispersions. Journal of Advanced Oxidation Technologies. vol 13(3): 274–280. doi: https://doi.org/10.1515/jaots-2010-0305.

Hobbs JP, McDonald CA. 2010. Increased seawater temperature and decreased dissolved oxygen triggers fish kill at the Cocos (Keeling) Islands Indian Ocean. Journal of Fish Biology. vol 77(6): 1219–1229. doi: https://doi.org/10.1111/j.1095-8649.2010.02726.x.

Ismail HTH, Mahboub HHH. 2016. Effect of acute exposure to nonylphenol on biochemical, hormonal, and hematological parameters and muscle tissues residues of Nile tilapia; Oreochromis niloticus. Veterinary world. vol 9(6): 616–625. doi: https://doi.org/10.14202%2Fvetworld.2016.616–625.

Ivanković T, Hrenović J. 2010. Surfactants in the environment. Archives of Industrial Hygiene and Toxicology. vol 61(1): 95–110. doi: https://doi.org/10.2478/10004-1254-61-2010-1943.

Krams IA, Suraka V, Rantala MJ, Sepp T, Mierauskas P, Vrublevska J, Krama T. 2013. Acute infection of
avian malaria impairs concentration of haemoglobin and survival in juvenile altricial birds. *Journal of Zoology*. vol 291(1): 34–41. doi: https://doi.org/10.1111/jzo.12043.

Lazado CC, Caipang CMA, Gallage S, Brinchmann MF, Kiron V. 2010. Expression profiles of genes associated with immune response and oxidative stress in Atlantic cod, *Gadus morhua* head kidney leukocytes modulated by live and heat-inactivated intestinal bacteria. *Comparative Biochemistry and Physiology Part B: Biochemistry and Molecular Biology*. vol 155(3): 249–255. doi: https://doi.org/10.1016/j.cbpb.2009.11.006.

Lee JA, Kim JW, Oh SY, Yi SK, Noh I, Ishimatsu A, Kim WS. 2012. Effect of low dissolved oxygen on the oxygen consumption rate and rhythm of the mudskipper *Scartelaos gigas* (Pisces, Gobiidae). * Fisheries Science*. vol 78(5): 1013–1022. doi: https://doi.org/10.1016/j.scitotenv.2014.02.053.

Luczyńska J, Paszczyk B, Łuczyński MJ. 2018. Fish as a bioindicator of heavy metals pollution in aquatic ecosystem of Pluszne Lake, Poland, and risk assessment for consumer’s health. *Ecotoxicology and Environmental Safety*. vol 153: 60–67. doi: https://doi.org/10.1016/j.ecoenv.2018.01.057.

Maftuch M. 2018. Hematological Analysis of Nile Tilapia (*Oreochromis niloticus*) and Striped Catfish (*Pangasius hypophthalmus*) using Hematology Analyzer Tool Software at Fish Breeding Center Jojogan, Tuban, East Java. *Research Journal of Life Science*. vol 5(2): 107–115. doi: https://doi.org/10.21776/ub.rjls.2018.005.02.4.

Meffe R, de Bustamante I. 2014. Emerging organic contaminants in surface water and groundwater: a first overview of the situation in Italy. *Science of the Total Environment*. vol 481: 280–295. doi: https://doi.org/10.1016/j.scitotenv.2014.02.053.

Milla S, Depiereux S, Kestemont P. 2011. The effects of estrogenic and androgenic endocrine disruptors on the immune system of fish: a review. *Ecotoxicology*. vol 20(2): 305–319. doi: https://doi.org/10.1007/s10646-010-0588-7.

Nardocci G, Navarro C, Cortés PP, Imarai M, Montoya M, Valenzuela B, Jara P, Acuña-Castillo C, Fernández R. 2014. Neuroendocrine mechanisms for immune system regulation during stress in fish. *Fish & Shellfish Immunology*. vol 40(2): 531–538. doi: https://doi.org/10.1016/j.fsi.2014.08.001.

Nivelle R, Gennotte V, Kalala EJ, Ngoc NB, Muller M, Mélard C, Rougeot C. 2019. Temperature preference of Nile tilapia (*Oreochromis niloticus*) juveniles induces spontaneous sex reversal. *PLoS One*. vol 14(2): 1–19. doi: https://doi.org/10.1371/journal.pone.0212504.

Oğuz AR. 2015. A histological study of the kidney structure of Van fish (*Alburnus tarichi*) acclimated to highly alkaline water and freshwater. *Marine and Freshwater Behaviour and Physiology*. vol 48(2): 135–144. doi: https://doi.org/10.1080/10236244.2015.1004838.

Osman AGM. 2012. Biomarkers in Nile tilapia *Oreochromis niloticus niloticus* (Linnaeus, 1758) to assess the impacts of river Nile pollution: bioaccumulation, biochemical and tissues biomarkers. *Journal of Environmental Protection*. vol 3(8): 966–977. doi: https://doi.org/10.4236/jep.2012.328112.

Patty SI, Afrah H, Abdul MS. 2015. Zat hara (fosfat, nitrat), oksigen terlarut dan pH kaitannya dengan kesuburan di perairan Jukumera, Pulau Buru. *Jurnal Pesisir dan Laut Tropis*. vol 3(1): 43–50. doi: https://doi.org/10.35800/jplt.3.1.2015.9578.

Rajan DS. 2015. An evaluation of the effect of a detergent on dissolved oxygen consumption rate of Anabas testudineus. *International Journal of Fisheries and Aquatic Studies*. vol 2(6): 46–48.

Ramachandra TV, Mahapatra DM, Asulabha KS, Varghese S. 2017. Foaming or algal bloom in water bodies of India: remedial measures–restrict phosphate (P) based detergents. [Report], Bangalore: Energy & Wetlands Research Group, Centre for Ecological Sciences, Indian Institute of Science.

Rebelo S, Asok AK, Mundayoor S, Jisha MS. 2014. Surfactants: toxicity, remediation and green surfactants. *Environmental chemistry letters*. vol 12(2): 275–287. doi: https://doi.org/10.1007/s10311-014-0466-2.

Ribas JLC, Zampronio AR, Silva de Assis HC. 2016. Effects of trophic exposure to diclofenac and dexamethasone on hematological parameters and immune response in freshwater fish. *Environmental Toxicology and Chemistry*. vol 35(4): 975–982. doi: https://doi.org/10.1007/1022.3240.

Sabilu K. 2010. Dampak toksisitas nikel terhadap kondisi hematologi ikan bandeng *Chanos chanos* Forsskall, studi lanjut respon fisiologi. *Paradigma*. vol 14(2): 205–216.

Sadauskas-Henrique H, Sakuragui MM, Paulino MG, Fernandes MN. 2011. Using condition factor and blood variable biomarkers in fish to assess water quality. *Environmental Monitoring and Assessment*. vol 181(1-4): 29–42. doi: https://doi.org/10.1007/s10661-010-1810-z.

Saparuddin A, Arbain. 2018. Biological test of the laundry industry toxicity of detergents and concentration of hemoglobin in tilapia (*Oreochromis niloticus*). Proceeding IOP Conference Series: Earth and Environmental Science. December 3–4, 2018. Kolaka: USN Kolaka–ADRI International Conference on Sustainable Coastal–Community Development. vol 382: 3–4.

Satheeshkumar P, Ananthan G, Kumar DS, Jagadeesan L. 2012. Haematology and biochemical parameters of different feeding behaviour of teleost fishes from Vellar estuary, India. *Comparative Clinical Pathology*. vol 21(6): 1187–1191. doi: https://doi.org/10.1007/s00580-011-1259-7.

Scapigliati G. 2013. Functional aspects of fish

---

Vol 8(1), June 2020

Biogenesis 77
lymphocytes. Developmental & Comparative Immunology. vol 41(2): 200–208. doi: https://doi.org/10.1016/j.dci.2013.05.012.

Seriani R, Abessa DMDS, Pereira CD, Kirschbaum AA, Assunção A, Ranzani-Paiva MJT. 2013. Influence of seasonality and pollution on the hematological parameters of the estuarine fish Centropomus parallelus. Brazilian Journal of Oceanography. vol 61(2): 105–111. doi: http://dx.doi.org/10.1590/S1679-87592013000200003.

Siburian AF, Nirmala K, Supriyono E. 2019. Evaluasi penggunaan jenis selter berbeda terhadap respons stres dan kinerja produksi penderan lobster air tawar Cherax quadricarinatus dalam sistem resirkulasi. Jurnal Riset Akuakultur. vol 13(4): 297–307. doi: http://dx.doi.org/10.15578/jra.13.4.2018.297-307.

Sobrino-Figueroa AS. 2013. Evaluation of oxidative stress and genetic damage caused by detergents in the zebrafish Danio rerio (Cyprinidae). Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology. vol 165(4): 528–532. doi: https://doi.org/10.1016/j.cbpa.2013.03.026.

Srinet SS, Basak A, Ghosh P, Chatterjee J. 2017. Separation of anionic surfactant in paste form from its aqueous solutions using foam fractionation. Journal of Environmental Chemical Engineering. vol 5(2): 1586–1598. doi: https://doi.org/10.1016/j.jece.2017.02.008.

Sugito S, Nurliana N, Aliza D, Samadi S. 2014. Diferensial leukosit dan ketahanan hidup pada uji tantang Aeromonas hydrophila ikan nila yang diberi stres panas dan suplementasi tepung daun jalah dalam pakan. Jurnal Kedokteran Hewan. vol 8(2): 158–163.

Sumisha A, Arthanareeswaran G, Thyavan YL, Ismail AF, Chakraborty S. 2015. Treatment of laundry wastewater using polyethersulfone/polyvinylpyrollidone ultrafiltration membranes. Ecotoxicology and Environmental Safety. vol 121: 174–179. doi: https://doi.org/10.1016/j.ecoenv.2015.04.004.

Tort L. 2011. Stress and immune modulation in fish. Developmental & Comparative Immunology. vol 35(12): 1366–1375. doi: https://doi.org/10.1016/j.dci.2011.07.002.

Tran-Duy A, van Dam AA, Schrama JW. 2012. Feed intake, growth and metabolism of Nile tilapia (Oreochromis niloticus) in relation to dissolved oxygen concentration. Aquaculture Research. vol 43(5): 730–744. doi: 10.1111/j.1365-2109.2011.02882.x.

Utomo WP, Nugraheni ZV, Rosyidah A, Shafwah OM, Naashih LK, Nurfitria N, Ullifdrayani IF. 2018. Penurunan Kadar Surfactan Anionik dan Fosfat dalam Air Limbah Laundry di Kawasan Keputih, Surabaya menggunakan Karbon Aktif. Akta Kimia Indonesia. vol 3(1): 127-140. doi: http://dx.doi.org/10.12962/j25493736.v3i1.3528.

Uzma S, Khan S, Murad W, Taimur N, Azizullah A. 2018. Phytotoxic effects of two commonly used laundry detergents on germination, growth, and biochemical characteristics of maize (Zea mays L.) seedlings. Environmental Monitoring and Assessment. vol 190(11): 1–14. doi: https://doi.org/10.1007/s10661-018-7031-6.

Velisek J, Stara A, Kolarova J, Svobodova Z. 2011. Biochemical, physiological and morphological responses in common carp (Cyprinus carpio L.) after long-term exposure to terbutryn in real environmental concentration. Pesticide Biochemistry and Physiology. vol 100(3): 305–313. doi: https://doi.org/10.1016/j.pestbp.2011.05.004.

Verdia P, Gunaratne HQN, Goh TY, Jacquemin J, Blesic M. 2016. A class of efficient short-chain fluorinated catanionic surfactants. Green Chemistry. vol 18(5): 1234–1239. doi: https://doi.org/10.1039/C5GC02790F.

Yuliani RL, Purwanti E, Pantiwati Y. 2015. Pengaruh Limbah Detergen Industri Laundry terhadap Mortalitas dan Indeks Fisiologi Ikan Nila (Oreochromis niloticus). Prosiding Biologi, Sains, Lingkungan dan Pembelajarannya. Surakarta: FKIP UNS. vol 12(1): 822–828.

Zafalon-Silva B, Zebral YD, Bianchini A, Da Rosa CE, Marins LF, Colares EP, Martinez PE, Bobrowski VL, Robaldo RB. 2017. Erythrocyte nuclear abnormalities and leukocyte profile in the Antarctic fish Notothenia coriiceps after exposure to short- and long-term heat stress. Polar Biology. vol 40(9): 1755–1760. doi: https://doi.org/10.1007/s00300-017-2099-y.

Zainuddin A, Putranto TWC, Irawan B, Soegianto A. 2019. Effect of sub-lethal lead exposure at different salinities on osmoregulation and hematological changes in tilapia, Oreochromis niloticus. Fisheries & Aquatic Life. vol 25(3): 173–185. doi: https://doi.org/10.1515/aapf-2017-0017.

Zuhrawati NA. 2014. Pengaruh peningkatan suhu terhadap kadar hemoglobin dan nilai hematokrit ikan nila (Oreochromis niloticus). Jurnal Medika Veterinaria. vol 8(1): 84-86.