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Fish Growth Performance in RAS Pond Using Hydrocyclone Mechanical Filter

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Abstract: The high feeding and the metabolic output of the fish in intensive aquaculture can cause various problem, such as poor water quality and slowing down the fish growth performance. Recirculating Aquaculture System (RAS) is a solution to maintain water quality. Unfortunately, the conventional mechanical filter in RAS such as japmat is inefficient. One strategy that can be applied is to use a hydrocyclone. This research aims to observe the fish growth performance in RAS pond using hydrocyclone mechanical filter and its comparison with the use of japmat. Research method was performed by comparing hydrocyclone and japmat in the pond with the RAS system. The research design is completely randomized design (CRD), with three replications in each treatment. The research was carried out through five stages, namely hydrocyclone set-up, RAS ponds set-up, water quality analysis, fish growth measurement, and statistical analysis. Based on the Independent Samples Test, the use of hydrocyclone mechanical filters has a significant effect ($P<0.05$) on the measured water quality parameters (DO, Temperature, pH, TDS, NH_3) except for NO_2. Hydrocyclone significantly affect Average Daily Growth and Specific Daily Growth parameters. Whilst, the Survival Rate and Feed Conversion Ratio parameters, it did not give significant effect.

Keywords: Aquaculture; Hydrocyclone; Mechanical filter; Recirculating system

Introduction

Intensive aquaculture is characterized by high stocking densities and the full use of highly nutritious formula feed to achieve high production (Shitu et al., 2020; Inayah et al., 2023). This high feeding and the metabolic output of the fish will result in an increase in nitrogen compounds and organic matter left behind in the water, which can cause various problems such as reduced dissolved oxygen, eutrophication, and the growth of bacteria that can cause disease (Sabu et al., 2021; Hoang et al., 2020; Abdel-Tawwab et al., 2020). One of the solutions to reduce the problems caused by wastewater is to change the water. However, changing large amounts of water every day is a waste of water resources and causes pollution (Nadiro et al., 2023).

Poor water conditions can also inhibit fish growth performance. Aquaculture ponds that contain high particles from the left-over feed and fish excretion can increase the NH_3, NO_2, TDS in water, and decrease the pH and DO, which all these parameters are needed to be in the optimum level to accelerate the fish growth (de Silva et al., 2022; Laza et al., 2021; Setyono et al., 2023). Studies have shown that exposure to suspended sediments can impact the gill structure and microbiome of fish larvae, potentially influencing the distribution patterns of fish assemblages (Hess et al., 2015).

Recirculating Aquaculture System (RAS) is a solution to save water and protect the environment. RAS has the concept of reusing water from the pond, which has passed through physical, chemical, and biological filters (El-Hashash et al., 2023; Sterling, 2022). Physical filter or usually called with mechanical filter. In a

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mechanical filter, water originating from a pond containing metabolic waste and other suspended particles passes through a mesh or layer filter which traps or filters suspended particles on the surface of the mechanical filter layer. This aims to reduce the workload of the subsequent filter room. If dirt in the form of solid particles or suspended particles can be filtered in this mechanical filter, then the filter room will not be burdened with filtering coarse particles (Henares et al., 2019).

The types of mechanical filters that are widely used by cultivators are sponges, brushes, fibers, cotton fibers. There are many types of cotton fiber, such as dacron cotton, bio foam, japmat, and matala. Conceptually, all types of mechanical filters are the same, namely filtering solid particles using several densities (Priono & Satyani, 2012). The advantage of the mechanical filter is that it is easy to clean and can be reused, but with high fish density and high metabolic output, the mechanical filter gets dirty easily, so it must be cleaned at least once a week. The washing process is quite complex, because it has to opened the entire filter chamber, remove the filter materials, and then wash them.

Hydrocyclone is a device for separating dirt particles that requires minimal maintenance. The function of the hydrocyclone is based on the pressure difference, centrifugal and centripetal forces formed by the water vortex. The centrifugal force of the vortex causes the particles in the water to be dispersed away from the vortex, and the pressure difference formed in the hydrocyclone moves the filtered and unfiltered water. In this hydrocyclone there are no moving objects or materials or tools, the entire filtration process is operated by water flow and the geometric shape of the hydrocyclone device itself (Bashir, 2015). According to Tavares et al. (2002) hydrocyclones are very sensitive to particle size distribution and density differences. The separation performance for most high-pressure hydrocyclones is with densities above 2 g/cm^3 and fine particles below 212 µm. Because the separation performance of the hydrocyclone can be improved by increasing the centrifugal force difference between the solid and the liquid.

Unfortunately, the mechanical filter in RAS always needs to be cleaned at least once a week which makes the mechanism inefficient because it wastes a lot of time for the fish farmers. One strategy that can be applied is to use a hydrocyclone that utilizes centrifugal force to be able to precipitate dirt particles in aquaculture wastewater. The famers only need to open the valve of hydrocyclone to discharge the effluent. Hence, it can shorten the period of cleaning the filters, and if the filter's purification can be done easily, it can enhance the quality of the water and increase the fish growth performance. This research aims to observe the fish growth performance in RAS pond using hydrocyclone mechanical filter and its comparison with the use of japmat.

Method

This research was performed on Juny to August 2023, by comparing two treatments in the pond with the RAS system, treatment (A) using a japmat filter, and treatment (B) using a hydrocyclone filter. Each treatment has three repetitions that randomized in placement, so the research design is completely randomized design (CRD).

Hydrocyclone Set-Up

The manufacture of the hydrocyclone begins with the design of the hydrocyclone. The hydrocyclone is made using an iron drum with a height of 70 cm and a diameter of 37 cm. Iron drum tip was cut and formed into a 17 cm diameter cone with a 3 cm diameter hole for pipe installation. At a height of 28 cm from the bottom of the drum surface, a 5.08 cm hole was made for the inlet pipe, and at a height of 17 cm from the bottom of the drum surface, a 5.08 cm hole was made for the outlet pipe. At the bottom of the drum, a 2.54 cm hole is made to install a faucet to facilitate hydrocyclone backwash. The japmat was made from the fiber with a small pore size.

RAS Ponds Set-Up

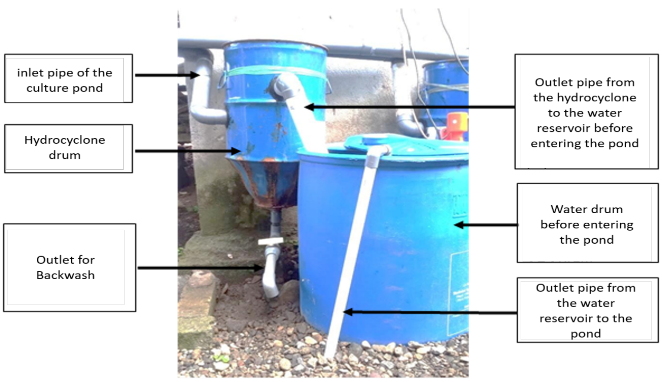

Figure 1. Hydrocyclone in mechanical filter

This reseach was used a 1.5 m diameter and 1.2 m high tarpaulin pond with aquaculture intensive methods. The commodity was tilapia with a length range of 11-14 cm and a weight of 100-160 g with a stocking density of 60 fish/m^3. Each pond was given a mechanical filter according to the research treatment. A pump was also installed to help with water recirculation and an aerator for oxygen supply. Feeding was conducted with T78-3 brand pellets three times a day with the amount of feed 3% of the tilapia weight (Rahmawati et al., 2021). Figure 1 and 2 exhibits the set up of both treatments using hydrocyclone and japmat filter.

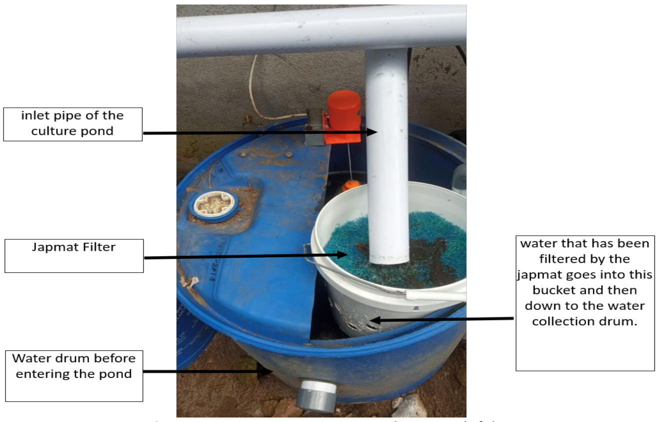

Figure 2. Japmat in mechanical filter

Water Quality Analysis

Sampling of pond water for water quality tests was conducted every day for 30 days, with parameters such as Dissolved Oxygen (DO), pH, temperature. While the parameters of Total Dissolved Solids, nitrite, nitrate were measured on days 7, 14, 21, and 28.

Survival Rate

Measurement of fish survival rate was conducted to determine hydrocyclone treatment could increase the number of fish alive at the end of the observation. Survival rate calculation used the following formula:

$$Survival\ Rate = \frac{Nt}{No} x100\% \quad (1)$$

With Nt as final number of tilapia, and No as initial number of tilapia (Stejskal et al., 2021).

Fish Growth Performance

Fish growth performances are used to determine the impact of using hydrocyclone on mechanical filters on fish growth. Fish growth parameters in this study are Average Daily Growth (ADG), Specific Growth Rate (SGR), and Feed Conversion Ratio (FCR) with the following formula:

$$FCR = \frac{Wt - Wo}{f} \quad (2)$$

With Wt as weight of fish at the end of treatment, Wo as Fish weight at the beginning of treatment, and f as the amount of feed given (Augustine et al., 2020).

$$ADG = \frac{ABW2 - ABW1}{1st\ and\ 2nd\ sampling\ period} \quad (3)$$

With ABW1 as initial weight (g), and ABW2 as final weight (g) (Kurniawan et al., 2014).

$$SGR = \frac{lnWt - LnWo}{T} x100\% \quad (4)$$

With Wt as Average weight of fish at the beginning of research (g), and Wo as Average weight of fish at the end of the research (g) (Sari et al., 2022).

Statistical Analysis

The data that was obtained from laboratory measurements were then statistically analyzed with the Independent Samples Test to determine the effect of using different mechanical filters on the parameters measured. Statistical analysis was performed with the SPSS 16 for windows program. Statistical analysis is conducted through the stages of descriptive analysis, assumption testing, to independent sample tests. Independent sample tests are carried out after the variance homogeneity test.

Result and Discussion

Water Quality

Water quality measurements were conducted to determine the effect of hydrocyclone on water quality. The results obtained showed that the use hydrocyclone affected the DO, pH, and temperature values of the pond. As seen in Table 1, the DO value in the pond using the hydrocyclone was found to be at an average of 17.81 mg/L higher than in the pond using the japmat which was at an average of 15.20 mg/L. The water temperature in the rearing ponds showed a slight difference in water temperature for both filters, which was 27.54°C for the hydrocyclone and 28.09°C for the japmat. Meanwhile, the pH of the pond water shows that the pond using japmat has a lower pH of 6.64 compared to the pond using hydrocyclone which is 7.32.

Table 1. Result of Daily Water Quality Test

Daily water quality parameter	Japmat	Hydrocyclone	Optimal level	P value
DO (mg/L)	15.20±2.56	17.81 ± 1.21	> 4 mg/L[a]	0.00
pH	6.64 ± 0.57	7.32 ± 0.16	6.6 – 8.5[b]	0.00
Temperature (°C)	28.09 ± 0.35	27.54 ± 0.18	25 – 32°C [c]	0.00

Note: [a]Boyd & Tucker (1992), [b]Timmons & Ebeling (2013), [c]Wijayanti et al., (2019)

These results are in accordance with previous research that the type of mechanical filter will affect the organic particles that enter the pond, the more particles that enter, the inversely proportional to the DO value.

This is because organic particles will undergo decomposition which requires a lot of oxygen, so that the DO value can drop. The lower DO value will increase the temperature in the pond and make the pond more acidic (Hapsari et al., 2020). High water temperature is negatively correlated with low dissolved oxygen in intensive ponds (Szewczyk et al., 2023). The temperature sensitivity of organic matter (OM) degradation, which affects dissolved oxygen levels, increases with rising temperatures (Carbajal-Hernández & Sánchez-Fernández, 2016). In a study of intensive aquaculture ponds, water temperature and dissolved oxygen content varied between 22.54-31.48°C and 5.04-9.88 mg/L, respectively (Kikuchi et al., 2023). The dissolved oxygen concentration in a pond was negatively correlated with temperature variations in the air and pond water. Therefore, high water temperature is associated with low dissolved oxygen in intensive ponds.

Table 2. Result of Weekly Water Quality Test

Weekly water quality parameter	Japmat	Hydrocyclone	Optimal level	P value
NH_3 (mg/L)	9.22 ± 0.44	7.05 ± 0.35	< 0.05[a]	0.00
NO_2 (mg/L)	0.35 ± 0.26	0.02 ± 0.22	≤ 1[b]	0.16
TDS (mg/L)	296.50 ± 62.00	221.00 ± 10.64	< 1000[c]	0.01

Note: [a]Boyd & Tucker (1992); [b]Pillay & Kutty (2005); [c]Wijayanti et al., (2019)

The use of hydrocyclone also showed a significant effect on weekly measured water quality parameters such as NH_3 and TDS. TDS values in the ponds with hydrocyclone had a lower average of 221 mg/L compared to the Japmat ponds which had an average of 296.5 mg/L. NH_3 values in both ponds had levels above the optimal water quality value for aquaculture. DO values are inversely proportional to NH_3 and TDS values. Low DO values can inhibit the nitrification process which causes an increase in ammonia (Zhu et al., 2010; Park et al., 2016; Hong et al., 2017). The NO_2 value in the pond using the hydrocyclone was found to be at an average of 0.02 mg/L which was lower than the pond using the japmat at an average of 0.35 mg/L. Based on the Independent Samples Test, the use of hydrocyclone mechanical filters has a significant effect ($P < 0.05$) on the measured water quality parameters except for NO_2. Although hydrocyclone does not have a significant effect on NO_2, it has a better NO_2 value than japmat.

The effect of hydrocyclone filters on water quality is significant. Hydrocyclones with sorption filter elements can effectively purify irrigation water from mechanical impurities and microdrops of organic pollutants (Lamskova et al., 2022). The hydrocyclone's filter can lower the total dissolved solids by effectively reducing the concentration of impurities in the water. The modernization of the hydrocyclone's structural elements, such as the installation of an impeller on the outlet of the clarified product, increases the centrifugal force of the swirling liquid flow, leading to improved efficiency in cleaning water (Ovchinnikov et al., 2022). Hydrocyclones with filtering side surface drain pipes can significantly increase the degree of water purification from mechanical impurities (Lamskova et al., 2020). Overall, hydrocyclone filters have a positive impact on water quality by removing impurities and contaminants.

Survival Rate and Growth Rate

Water quality conditions in ponds that use hydrocyclone significantly affect fish growth parameters, especially in the parameters of Average Daily Growth and Specific Daily Growth. In the Survival Rate and Feed Conversion Ratio parameters, the use of hydrocyclone does not have a significant effect. Although it does not show a significant effect, the use of hyrocyclone produces better water quality than japmat which makes hydrocyclone have better SR and FCR values. From table 3 it can be seen that, the growth of tilapia in the aquaculture pond using hydrocyclone has better growth compared to tilapia cultured using japmat. This is because different mechanical filters have different filter effectiveness, the dirtier particles that can be filtered, the better the water quality in the cultivation pond which can cause maximum growth of fish (Sari et al., 2022). From Table 1 and 2 shows that the water qualities of hydrocylone's pond are better than japmat's, hence the fish growth are better in hydrocyclone.

Table 3. Result of Fish Growth Performance

Fish growth performance	Japmat	Hydrocylone	P value
Survival rate (%)	98.00 ± 2.64	99.67 ± 0.58	0.400
Average daily growth (gr)	1.63 ± 0.31	2.50 ± 0.22	0.016
Specific growth rate (gr)	38.90 ± 7.08	54.17 ± 3.74	0.017
Feed conversion ratio	6.48 ± 1.43	4.19 ± 0.36	0.055

As studied by Wei et al. (2019) low dissolved oxygen individually reduced larval blue crab survival by more than 90% compared to the control treatment, while low pH had no effect. However, in Liu et al. (2023), within 14-day experiments, the combined effects of low dissolved oxygen and low pH were additive and resulted in lower survival rates than the individual treatments. These findings suggest that both low dissolved oxygen and low pH can have acute effects on the survival of organisms in intensive ponds, and their combined effects may contribute to interannual variability and possible regional declines in fisheries (Saha et al., 2013). Water quality parameters have a significant effect on fish growth (Omweno et al., 2022; Tumwesigye et al., 2022).

Conclusion

According to the findings, ponds with hydrocyclone mechanical filters have better water quality than japmat mechanical filters. Fish growth in rearing ponds using fydrocyclone is better than japmat. The use of hydrocyclone provides time and energy efficiency for farmers in backwashing the particles left in the hydrocyclone.

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Author Contributions
Conceptualization, Aulia Rahmawati and Aulia Rahman; Data analysis, Febriyani Eka Supriatin; Drafting, Muhammad Nasim Mubarok; Review, Sri Andayani. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest
The authors declare no conflict of interest.

References

Abdel-Tawwab, M., Monier, M. N., & Abdelrhman, A. M. (2020). Effect of Dietary Multi- Stimulants Blend Supplementation on Performance, Digestive Enzymes, and Antioxidants Biomarkers of Common Carp, Cyprinus carpio L. and Its Resistance to Ammonia Toxicity. *Aquaculture*, *528*(735529), 1-8. https://doi.org/10.1016/j.aquaculture.2020.735529

Augustine, O., Eyuwunmi, F. A., & Bolanle, A. S. (2020). Practical Growth Performance and Nutrient Utilization of Catfish Clarias garipinus Fed Varying Inclusion Level of Fermented Unsieved Yellow Maize. *Journal of Natural Sciences Research*, *10*(6), 43-50. https://doi.org/10.7176/JNSR/10-6-06

Bashir, K. (2015). *Design and Fabrication of Cyclone Separator*. Gujarat: University of Gujarat.

Boyd, C. E., & Tucker, C. S. (1992). *Water Quality and Pond Soil Analysis for Aquaculture*. Auburn: University Auburn.

Carbajal-Hernández, J. J., & Sánchez-Fernández, L. P. (2016). Neural Network Modelling for Dissolved Oxygen Effects in Extensive Litopenaeus Vannamei Culture. In O. Pichardo-Lagunas, & S. Miranda-Jiménez. *Advances in Soft Computing* (pp. 132-140). Springer, Cham. https://doi.org/10.1007/978-3-319-62428-0_10

de Silva, B. C., Massago, H., de Andrade, J. I., Serafini, R. d., & Jatobá, A. (2022). Tilapia Nursery Stocking Densities in a Chemoautotrophic Biofloc System. *Ciência e Agrotecnologia*, *46*(e022321), 1-11. http://dx.doi.org/10.1590/1413-7054202246022321

El-Hashash, D. Z., Ali, S. A., Ashour, T. H., & Khater, E.-S. G. (2023). Evaluation of Settleable Solids Removal Methods in Recirculating Aquaculture System. Misr. *Journal of Agricultural Engineering*, *40*(1), 75-88. https://doi.org/10.21608/mjae.2022.173696.1089

Hapsari, A. W., Hutabarat, J., & Harwanto, D. (2020). Aplikasi Komposisi Filter yang Berbeda terhadap Kualitas Pertumbuhan dan Kelulushidupan Ikan Nila (Oreochromis niloticus) pada Sistem Resirkulasi. *Jurnal Sains Akuakultur Tropis*, *4*(1), 39-50. https://doi.org/10.14710/sat.v4i1.6437

Henares, M. N., Medeiros, M. V., & Camargo, A. F. (2019). Overview of Strategies that Contribute to The Environmental Sustainability of Pond Aquaculture: Rearing Systems, Residue Treatment, and Environmental Assessment Tools. *Reviews in Aquaculture*, *12*(1), 453-470. https://doi.org/10.1111/raq.12327

Hess, S., Wenger, A. S., Ainsworth, T. D., & Rummer, J. L. (2015). Exposure of Clownfish Larvae to Suspended Sediment Levels Found on the Great Barrier Reef: Impacts on Gill Structure and Microbiome. *Scientific Reports*, *5*(10561), 1-8. https://doi.org/10.1038/srep10561

Hoang, M. N., Nguyen, P. N., & Bossier, P. (2020). Water Quality, Animal Performance, Nutrient Budgets and Microbial Community in the Biofloc-Based Polyculture System of White Shrimp, Litopenaeus vannamei and Gray Mullet, Mugil cephalus. *Aquaculture*, *515*(734610), 1-11. https://doi.org/10.1016/j.aquaculture.2019.734610

Hong, X., Chen, Z., Zhao, C., & Yang, S. (2017). Nitrogen Transformation Under Different Dissolved Oxygen Levels by the Anoxygenic Phototrophic Bacterium Marichromatium gracile. *World Journal of Microbiology and Biothecnology*. https://doi.org/10.1007/s11274-017-2280-z

Inayah, Z. N., Musa, M., & Arfiati, D. (2023). Growth of Vannamei Shrimp (Litopenaeus vannamei) in

Intensive Cultivation Systems. *Jurnal Penelitian Pendidikan IPA*, *9*(10), 8821-8829. https://doi.org/10.29303/jppipa.v9i10.4278

Kikuchi, R., Ferreia, C. S., & Gerardo, R. (2023). Climatic Factors Affecting Water Quality under Natural Conditions: A Field Survey of a Local Reservoir. *International Journal of Environment and Climate Change*, *13*(5), 422-430. https://doi.org/10.9734/ijecc/2023/v13i51787

Kurniawan, A., Marsoedi, M., & Fadjar, M. (2014). Optimization Model of Paddlewheel as Water Quality Engineering Tool in Intensive Pond Culture of Vannamei Shrimp (Litopenaeus vannamei) in BBAP Situbondo, East Java, Indonesia. *Internation Journal of Agronomy and Agricultural Research*, *5*(5), 177-182. Retrieved from https://rb.gy/5x7lik

Lamskova, M. I., Filimonov, M. I., Novikov, A. E., & Borodychev, C. V. (2020). Modeling the Classification Ability of Filtering Hydrocyclone. Mathematical Modeling of Technical and Economic Systems in Agriculture II. *IOP Conference Series: Earth and Environmental Science*. https://doi.org/10.1088/1755-1315/577/1/012011

Lamskova, M. I., Filimonov, M. I., Novikov, A. E., & Novikov, A. I. (2022, April). Sorption filtration of organic microdrops in a hydrocyclone. In *IOP Conference Series: Earth and Environmental Science* (Vol. 1010, No. 1, p. 012114). IOP Publishing. https://doi.org/10.1088/1755-1315/1010/1/012114

Laza, E.-A., Caba, I. L., Olan, M., & Vladut, V. (2021). Biological Water Treatment in a Recirculating. *E3S Web of Conferences*, *286*(03013), 1-7. https://doi.org/10.1051/e3sconf/202128603013

Liu, W., Liu, S., Hassan, S. G., Cao, Y., Xu, L., Feng, D., & Zhang, H. (2023). A Novel Hybrid Model to Predict Dissolved Oxygen for Efficient Water Quality in Intensive Aquaculture. *IEEE Access*, *11*, 29162-29174. https://doi.org/10.1109/ACCESS.2023.3260089

Nadiro, V. N., Andayani, S., Widodo, M. S., & Nurhalisa, N. (2023). Different Stocking Density on Water Quality of Red Tilapia (Oreochromis sp) in Budikdamber System. *Jurnal Penelitian Pendidikan IPA*, *9*(4), 2030-2035. https://doi.org/10.29303/jppipa.v9i4.3236

Omweno, J. O., Getabu, A., Omondi, R., & Orina, P. S. (2022). Water Quality Effects on Growth and Survival of Oreochromis jipe and Oreochromis niloticus Species in Aquaculture. In S. Dincer, H. A. Takci, & M. S. Ozdenefe, *Water Quality - New Prespectives. Chapter Metrics Overview*. https://doi.org/10.5772/intechopen.106361

Ovchinnikov, A. S., Denisova, M. A., Pustovalov, E. V., Bocharnikov, V. S., Bocharnikova, O. V., & Kozinskaya, O. V. (2022). Modernization of structural elements of a hydrocyclone to improve the efficiency of irrigation water treatment. In *IOP Conference Series: Earth and Environmental Science* (Vol. 965, No. 1, p. 012017). IOP Publishing. https://doi.org/10.1088/1755-1315/965/1/012017

Park, C.-H., Kim, D.-H., & Han, G.-B. (2016). Optimizing Nutrient Removal in Municipal Wastewater Under Microalgal–Bacterial Symbiosis with Mesh Screen Separation. *Environmental Engineering Science*. https://doi.org/10.1089/ees.2016.0188

Pillay, T. V., & Kutty, M. N. (2005). *Aquaculture: Principles and Practices*. Oxford: Blackwell Pub.

Priono, B., & Satyani, D. (2012). Penggunaan Berbagai Jenis Filter untuk Pemeliharaan Ikan Hias Air Tawar di Akuarium. *Media Akuakultur*, *7*(2), 76-83. http://dx.doi.org/10.15578/ma.7.2.2012.76-83

Rahmawati, A., Dailami, M., & Supriatin, F. E. (2021). The Performance of Water Quality in Tilapia Pond Using Dutch Bucket and Deep Flow Technique. *Egyptian Journal of Aquatic Biology and Fisheries*, *25*(1), 885-897. https://doi.org/10.21608/ejabf.2021.156606

Sabu, E. A., Gonsalves, M. J., Sreepada, R. A., Shivaramu, M. S., & Ramaiah, N. (2021). Evaluation of the Physiological Bacterial Groups in a Tropical Biosecured, Zero-Exchange System Growing Whiteleg Shrimp, Litopenaeus vannamei. *Environmental Microbiology*, *81*, 335-346. https://doi.org/10.1007/s00248-020-01575-w

Saha, H., Saha, R. K., Kamilya, D., & Kumar, P. (2013). Low pH, Dissolved Oxygen and High Temperature Induces Thelohanellus rohita (Myxozoan) Infestation in Tropical Fish, Labeo rohita (Hamilton). *Journal of Parasitic Diseases*. https://doi.org/10.1007/s12639-012-0177-1

Sari, W. P., Zaidy, A. B., Haryadi, J., & Krettiawan, H. (2022). Efektivitas Jenis Filter pada Sistem Resirkulasi terhadap Kualitas Air dan Pertumbuhan Panjang Benih Pangasionodon hyphophthalamus. *Jurnal Penyuluhan Perikanan dan Kelautan*, *16*(2), 205-219. https://doi.org/10.33378/jppik.v16i2.351

Setyono, B. D., Al Baihaqi, L. W., Marzuki, M., Atmawinata, L. M., Fitria, S., & Affandi, R. I. (2023). Microbubble Technology to Improve Growth of Catfish (Clarias sp.). *Jurnal Penelitian Pendidikan IPA*, 9(9), 7373-7382. https://doi.org/10.29303/jppipa.v9i9.3433

Shitu, A., Zhu, S., Qi, W., Tadaa, M. A., Liu, D., & Ye, Z. (2020). Performance of Novel Sponge Biocarrier in

MBBR Treating Recirculating Aquaculture Systems Wastewater: Microbial Community and Kinetic Study. *Journal of Environmental Management*, *275*(111264), 1-12. https://doi.org/10.1016/j.jenvman.2020.111264

Stejskal, V., Matoušek, J., Sebesta, R., & Nowosad, J. (2021). Stocking Density Effect on Survival and Growth of Early Life Stages of Maraena Whitefish, Coregonus maraena (Actinopterygii: Salmoniformes: Salmonidae). *Acta Ichthyologica et Piscatoria*, *51*(2), 139-144. https://doi.org/10.3897/aiep.52.64119

Sterling, I. (2022). *Mechanical Filtration: The Most Common Type of Aquarium Filter*. Retrieved from https://fishlab.com/mechanical-filtration/

Szewczyk, C. J., Smith, E. M., & Benitez-Nelson, C. R. (2023). Temperature Sensitivity of Oxygen Demand Varies as a Function of Organic Matter Source. *Frontiers Marine Science*, *10*. https://doi.org/10.3389/fmars.2023.1133336

Tavares, L. M., Souza, L. L., Lima, J. R., & Possa, M. V. (2002). Modeling Classification in Small-diameter Hydrocyclones Under Variable Rhelogical Conditions. *Minerals Engineering*, *15*(8), 613-622. https://doi.org/10.1016/S0892-6875(02)00085-7

Timmons, M. B., & Ebeling, J. M. (2013). *Recirculating Aquaculture*. New York: Publishing Company LLC.

Tumwesigye, Z., Tumwesigye, W., Opio, F., Kemigabo, C., & Mujuni, B. (2022). The Effect of Water Quality on Aquaculture Productivity in Ibanda District, Uganda. *Aquaculture Journal*, *2*(1), 23-36. https://doi.org/10.3390/aquacj2010003

Wei, Y., Jiao, Y., An, D., Li, D., Li, W., & Wei, Q. (2019). Review of Dissolved Oxygen Detection Technology: From Laboratory Analysis to Online Intelligent Detection. *Sensors, 19(18), 3995.* https://doi.org/10.3390/s19183995

Wijayanti, M., Khotimah, H., Sasanti, A. D., Dwinanti, S. H., & Rarassari, M. A. (2019). Culturing of Nile Tilapia (Oreochromis niloticus) with Aquaponic System in Karang Endah Village, Gelumbung District, Muara Enim Regency South Sumatera. *Journal of Aquaculture and Fish Health*, *8*(3), 139-148. https://doi.org/10.20473/jafh.v8i3.14901

Zhu, L., Gao, R., Zhang, L., & Liu, L. (2010). Effect of Low Dissolve Oxygen on Nitrogen Removal in A^2/O Process. In *2010 4th International Conference on Bioinformatics and Biomedical Engineering* (pp. 1-4). IEEE. https://doi.org/10.1109/ICBBE.2010.5517466