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Phytoremediation of Aquaculture Wastewater Using *Persicaria odorata* and *Oenanthe javanica*

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ABSTRACT

This study evaluates the phytoremediation potential of Oenanthe javanica and Persicaria odorata for treating aquaculture wastewater over a 28-day treatment duration. Plant growth and water quality parameters were monitored to assess performance. P. odorata showed a higher relative growth rate (0.043 cm/day) than O. javanica (0.036 cm/day), suggesting better adaptability to aquatic conditions. Although most effluent parameters met acceptable aquaculture standards, Total Ammonia Nitrogen (TAN) remained elevated at 0.41 mg/L, exceeding the optimal threshold of 0.3 mg/L. P. odorata exhibited superior contaminant removal, reducing TAN by 26.79%, nitrate by 30.56%, and total dissolved solids (TDS) by 17.96%. In contrast, O. javanica achieved lower removal efficiencies: 11.39% for TAN, 25.00% for nitrate, and 11.81% for TDS. These results suggest that P. odorata is more effective in improving aquaculture wastewater quality, offering a viable, plant-based approach to mitigate nutrient loads. This study supports the integration of P. odorata in aquaculture systems as a sustainable and low-cost phytoremediation strategy.

Keywords: Aquaculture Wastewater, *Oenanthe javanica*, *Persicaria odorata*, Phytoremediation, Water Quality.

1. INTRODUCTION

According to the Department of Fisheries Malaysia, aquaculture is defined as any kind of activity of fish seed production, cultivation of seed, and farming for the purpose of raising fish and shellfish. Aquaculture activity in closed freshwater and brackish water/marine environments. Freshwater aquaculture statistically contributed an amount of 9652 tonnes to the whole fish production in Malaysia in 2024 [1]. Apart from that, the modern technologies of carp breeding induction as for instance and polyculture in static ponds and tanks, have effectively made a revolution. The freshwater aquaculture sector has become a fast-paced sector [2].

The expansion of the aquaculture industry, while significant, necessitates a critical assessment of its environmental impact, particularly concerning its substantial water demands and the discharge of high volumes of effluent. The degradation of water quality resulting from these activities has been directly linked to an increase in disease outbreaks and contamination of aquaculture products, leading to considerable economic losses [3]. Consequently, the development and implementation of effective wastewater treatment processes are essential for ensuring the long-term sustainability of aquaculture development in Malaysia. A diverse range of technologies exists for treating aquaculture wastewater, including physical methods like settling and mechanical filters, biological processes such as biofiltration and constructed wetlands, and

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chemical treatments like coagulation and ozonation. These alternatives are often combined to effectively remove suspended solids, nutrients, and other pollutants in ensuring decent water quality and sustainability [4].

While conventional physicochemical treatments for aquaculture wastewater have been applied, they often suffer from significant drawbacks, including high costs and a limited ability to remove all contaminants. They are also not environmentally friendly. For these reasons, research has increasingly focused on developing natural alternatives. Phytoremediation, a promising biological technique, utilizes plants and their associated microorganisms to effectively remove both organic and inorganic pollutants. This eco-friendly system offers a sustainable approach to improving the water quality of aquaculture effluents [5]. An ideal plant species for phytoremediation should demonstrate high uptake capacity for both organic and inorganic pollutants, exhibit robust growth in polluted water, and allow for easy control and efficient propagation to manage its dispersion [6].

Oenanthe javanica (also known as water celery) and *Persicaria odorata* (also known as Vietnamese coriander or kesum) were used in this study as phytoremediation plants. Both plants have been studied for their potential in phytoremediation, where the plants are used to remove, transfer, or stabilize contaminants from soil and water. These plants assimilate nutrients directly from the water by using their roots. These plants were chosen due to their high ability to grow well in the water with strong and dense root systems [7]. *Oenanthe javanica* is recognized for its ability to grow rapidly in polluted water and its high nitrogen removal efficiency, making it suitable for phytoremediation in aquatic environments [8]. Research demonstrated its effectiveness in removing nitrogen compounds and chemical oxygen demand from livestock wastewater when used in floating constructed wetlands, with high removal rates of total nitrogen (about 80%) and ammonium nitrogen (about 95%) after a treatment period [9]. The plant's biomass can be harvested and is considered safe for human consumption post-treatment, adding to its resource utilization potential in phytoremediation applications. However, a few studies have assessed the potential for this plant to be used for water and wastewater treatment. *Persicaria odorata* is rich in phenols and flavonoids, which contribute to its antioxidant, anti-inflammatory, and antibacterial properties. These compounds could potentially aid in the detoxification processes required for phytoremediation, although specific studies on this application are lacking [7], [10].

2. MATERIAL AND METHODS

2.1 Experimental Setup

The experiment was conducted in a greenhouse at the Faculty of Chemical Engineering & Technology, Universiti Malaysia Perlis, to evaluate the effectiveness of a Horizontal Subsurface Flow (HSSF) wetland system in treating fish tank wastewater. Figure 1 shows the experimental setup encompassing three distinct experimental units: one planted with *Oenanthe javanica*, another with *Persicaria odorata*, and a final control unit containing only soil. Over a duration of 28 days, the performance of each unit was monitored to assess its ability to improve the water quality of the effluents.

Each experimental unit container would have one replication to improve the significance of the experimental result. The aquaculture wastewater would automatically flow and recirculate from the wastewater inlet to the wastewater outlet by using a water pump for 28 days. Emergent plants are partly submerged under water in the soil and partly above the water. The aquaculture wastewater samples were analyzed by using a YSI ProPlus Water Quality meter on a weekly basis.

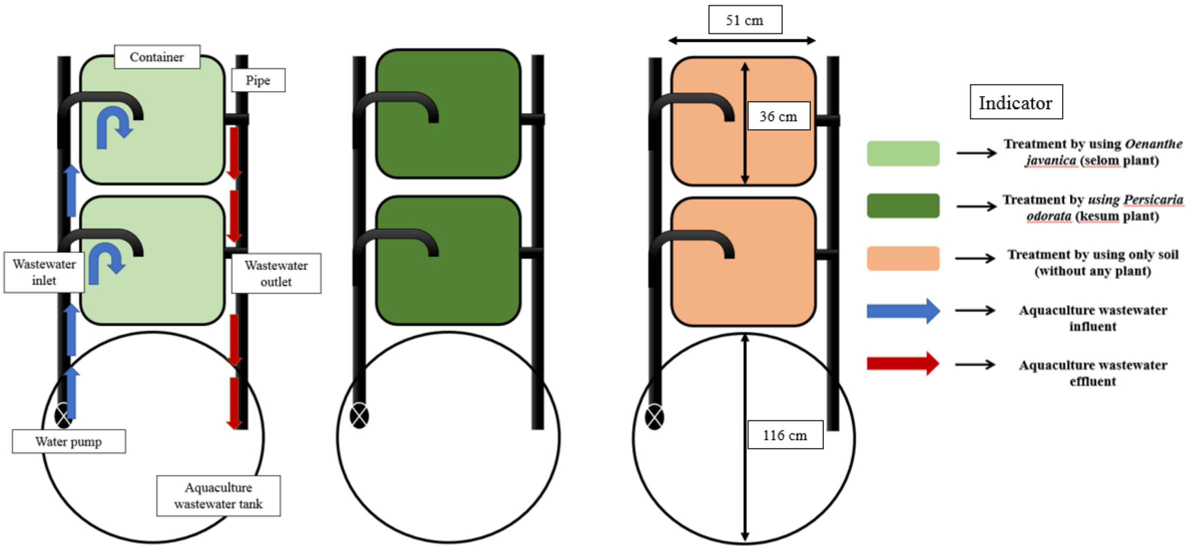


Figure 1: Experimental design of the phytoremediation system.

The *Oenanthe javanica and Persicaria odorata* plants were cultivated by their stem cutting from a healthy and non-flowering mother plant in tap water. A new root and shoot would appear from the cutting stems after the stems were planted in the experimental unit container for a few days. The type of soil that was used in the container was loam soil.

2.2 Sampling and Analysis

Raw aquaculture wastewater was collected from the aquaculture fish tank and from the experimental unit container of the HSF wetland in the greenhouse. The sample collected was analyzed for pH value, temperature, Total Dissolved Solids (TDS), Dissolved Oxygen (DO), Total Ammonia Nitrogen (TAN), and Nitrate. The data readings were taken weekly for 30 days. The readings were taken by using a YSI ProPlus Water Quality meter probe for pH and turbidity readings. The sensor was placed in the sample to be measured, and the sensor was quickly shaken to release any air bubbles. Then, the temperature readings were allowed to stabilize. Once the values were at a plateau state and stabilized, the measurement data were recorded.

The removal efficiency of the TAN and Nitrate was determined by measuring the concentration before and after treatment. Samples were collected at defined time intervals and analyzed for removal efficiency. The initial concentration (Co) and final concentration (Ct) of the pollutant were recorded, and the removal efficiency was calculated using the following equation [11]:

$$\text{Removal efficiency (\%)} = \frac{Co - Ct}{Co} \times 100 \quad (1)$$

Where: C_0 = the initial concentration (mg/L)
C_t = the concentration (mg/L) at the end of adsorption

The relative growth rate (RGR) of the plants was calculated to assess their growth performance over time. Plant biomass was recorded at two different growth stages. The height of three sample of each plant from six experimental unit containers were measured for their height by using a measuring tape. The RGR was calculated by using the following formula [12]:

$$\text{RGR} = \frac{Ln\,Xt - Ln\,Xo}{\Delta t} \quad (2)$$

Where: RGR = relative growth rate

Xt = length of the plant at the end of the experimental period
Xo = length of the plant at the start of the experimental period
Δt = observation period

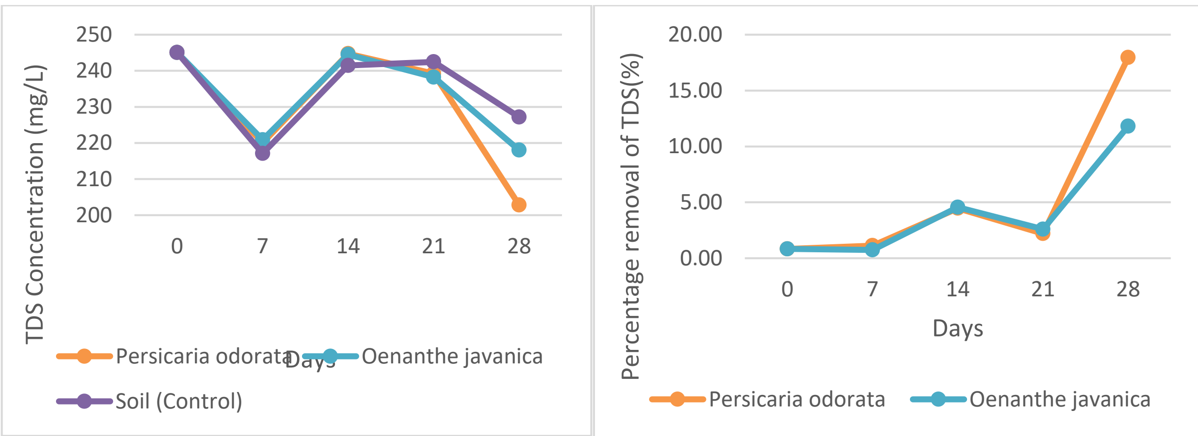
3. RESULTS AND DISCUSSION

3.1 Total Dissolved Solids (TDS) Concentration and Removal Efficiency

From the plotted graph of Total Dissolved Solids (TDS) against observation period in Figure 2 (a), the results from all treatments showed a similar decrement in the concentration in aquaculture wastewater. The high concentration level of TDS at day 0 and day 28 in the soil (control) was largely contributed to by uneaten fish feed and fish feces. The reductions of TDS in both macrophytes experimental units were more likely caused by the capacity of the plants to absorb inorganic mineral salts through their root and store them as inorganic materials [8]. The high concentration level of TDS in the soil (control) experimental units lowers the pH value of the wastewater [9].

Some parts of the plants have the capacity to absorb the dissolved salts over their surface. Adsorption phenomena have already been reported by several researchers [13]. The results obtained from this phytoremediation study by using two different types of macrophytes satisfied the theory that macrophytes were able to reduce TDS to a tolerable limit in aquaculture wastewater. The optimum concentration level of TDS was below 400 mg/L in aquaculture wastewater. From the results obtained, the TDS concentration level was already at the optimum range from day 0, which was 245.05 mg/L, and was managed to be reduced by using a phytoremediation system. Hence, this experiment proved that *Persicaria odorata* and *Oenanthe javanica* had the capacity to reduce TDS.

Figure 2 (b) illustrates the removal efficiency of TDS between *Persicaria odorata* and *Oenanthe javanica* plants. From this figure, the removal efficiency of TDS achieved 18.0% and 11.8% for each plant, respectively, at the end of 28 days of treatment. The reduction efficiency of TDS observed in this study was an indication that macrophytes have the potential to reduce the TDS, which was similar to the observation of several researchers [13].



(a) (b)

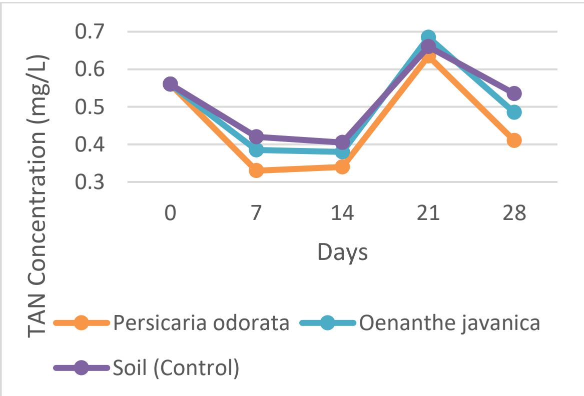
Figure 2: (a) Total Dissolved Solids concentration of effluent against the observation period and (b) removal efficiency of TDS.

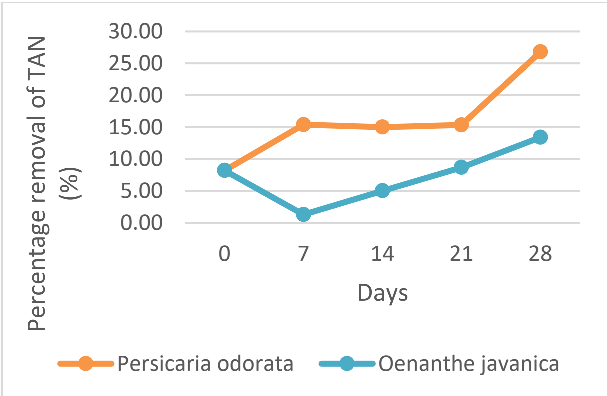
3.2 Total Ammonia Nitrogen (TAN) Concentration and Removal Efficiency

The plotted graph in Figure 3 (a) shows the trend for TAN concentration for both macrophytes, which are *Persicaria odorata* and *Oenanthe javanica,* for 28 days. A similar decrease in TAN concentration in the effluent of aquaculture wastewater was observed by day 7 for both *Persicaria odorata* and *Oenanthe javanica*. The main reason for the TAN concentration level in effluent aquaculture wastewater dropped significantly after going through the phytoremediation process was due to both direct plant uptake and the consumption of ammonia in nitrification [14]. On day 28, the TAN concentration level in *Persicaria odorata* treatment was 0.41 mg/L, while for *Oenanthe javanica* treatment, it was 0.49 mg/L. Thus, *Persicaria odorata* has higher uptake of TAN compared to *Oenanthe javanica,* as this nutrient was essential for the plants as their main source of nitrogen [15].

The high peak of the graph line at day 21 illustrates that the high-level ammonia was contributed by high levels of fish feces and fish feeds [16]. The plant was unable to reduce more ammonia as a small number of plants were harvested due to the aphid infection. Nitrogen promotes plant growth and is vital for the photosynthesis process to take place. At the end of the observation period, *Persicaria odorata* and *Oenanthe javanica* were unable to maintain the TAN concentration of the wastewater within the optimum range of less than 0.3 mg/L, with concentration values of 0.41 mg/L and 0.49 mg/L, respectively.

Figure 3 (b) shows that the removal efficiency of Total Ammonia Nitrogen (TAN) after 28 days of phytoremediation was 26.79% for *Persicaria odorata* and 13.39% for *Oenanthe javanica*. These results confirm the capacity of both species to reduce TAN concentrations, aligning with previous observations [17]. *P. odorata* exhibited a consistent increase in TAN removal throughout the experiment, while *O. javanica* showed an initial decline to 1.28% on day 7, followed by a gradual increase from day 14 onwards. The progressive improvement in TAN removal is attributable to enhanced plant growth, as increased biomass supports greater nutrient uptake efficiency [18]





(a) (b)

Figure 3: (a) TAN concentration of effluent against observation period and (b) TAN removal efficiency.

3.3 Nitrate Concentration and Removal Efficiency

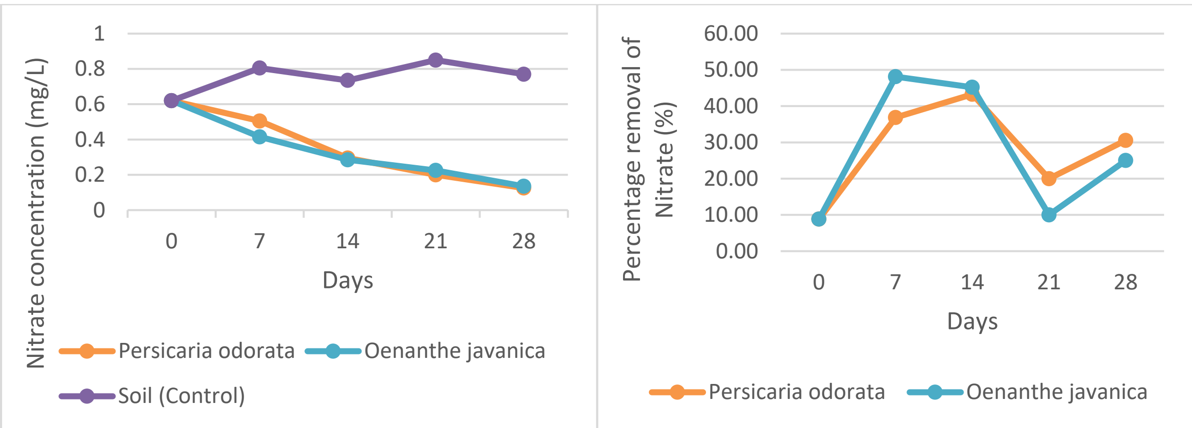
Graph in Figure 4 (a) shows that nitrate concentration level in aquaculture wastewater was decreasing gradually up to day 28 for both *P. odorata* and *O. javanica*. For *P. odorata*, the nitrate concentration had a similar trend to *O. javanica* macrophytes at day 14 to 28. For the soil (control) experimental units, the nitrate gradually increased to 0.77 mg/L because the nitrification process took place in that experimental unit. Nitrification is a process that reduces the nitrogen compounds, primarily ammonia, which is sequentially oxidized to nitrite and nitrate.

It occurred when the ammonia present was oxidized to nitrite by a bacterium, a group called Ammonia-Oxidizing Bacteria (AOB), while Ammonia-Oxidizing Archaea (AOA) oxidized ammonia to nitrite and finally produced nitrate [19].

For control systems, the aquaculture wastewater was exposed to direct sunlight. Hence, a greater amount of dissolved oxygen was released by the filamentous algae in the wastewater through photosynthesis [18]. This promoted the frequent nitrification process since abundant oxygen was dissolved and used in the nitrification process, leading to an increase in the nitrate concentration level in the aquaculture wastewater [20]. At the end of the observation period, *Persicaria odorata* and *Oenanthe javanica* managed to maintain the nitrate concentration of the wastewater within the optimum range of less than 0.50 mg/L, with concentration values of 0.13 mg/L and 0.14 mg/L, respectively.

The nitrate was absorbed by the plants as a nutrient source. Figure 4 (b) shows the nitrate removal performance of *Persicaria odorata, which* achieved the maximum percentage of 43.27% at 14 days of the phytoremediation period, while *Oenanthe javanica* achieved the maximum percentage of 48.13% at 7 days of the phytoremediation period. However, the percentage decreased by 30.56% and 25% for *Persicaria odorata* and *Oenanthe Javanica,* respectively, at the end of the phytoremediation period. The decreasing nitrate removal percentage was caused by the increase in the plants' maturity and the plants were in a diminishing growth phase where the growth of the plant would finally slow down and come to a stop (steady state) that eventually reduces the capacity of the plants to uptake nitrate. The reduction of nitrate in the phytoremediation process is also due to denitrifying bacteria that metabolize nitrates, reducing them to atmospheric nitrogen and thereby depleting the nitrate concentration [21].

Similar observations were reported by several researchers as the increase in nitrate concentration of aquaculture wastewater of tilapia cultivation on day 7 of the phytoremediation period [22]. This was in line with the significant decline of ammonia concentration on day 7 due to the conversion of ammonia to nitrate occurring much more intensively at *Oenanthe javanica* treatment, which made the plants take up more nitrate than TAN. Therefore, during 7 days of experiment with *Oenanthe javanica*, ammonia conversion into nitrate was at the highest level as the reduction of ammonia concentration was influenced by the increase of nitrate concentration as demonstrated in Figure 4 (b) [23].



(a) (b)

Figure 4: (a) Nitrate concentration of effluent against observation period and (b) Nitrate removal efficiency.

3.4 Growth Performance of *Persicaria odorata* and *Oenanthe javanica*

Figure 5 presents the average plant height over the 28-day observation period. At day 0, the mean height of *P. odorata* was 17.75 ± 0.07 cm, while *O. javanica* averaged 13.37 ± 0.19 cm. After 28 days of phytoremediation, *P. odorata* attained an average height of 58.55 ± 0.92 cm, whereas *O. javanica* reached 36.67 ± 0.20 cm, accompanied by the growth of abundant root hairs and elongated lateral branches. Both species displayed consistent and significant increases at each 7-day interval. A comparable growth pattern was reported by using *Chrysopogon zizanioides* (vetiver grass) with a noticeable increase in height during phytoremediation [24].

The calculated average relative growth rates were 0.043 cm/day for *P. odorata* and 0.036 cm/day for *O. javanica*, indicating that *P. odorata* exhibited a higher growth rate. The positive height increment observed in both species can be attributed to the availability of sufficient nutrients in the aquaculture wastewater, which supported their growth. These nutrients were derived from inorganic dissolved compounds as well as the mineralization of dissolved solids, likely originating from uneaten feed and fish excretion [7]. The observed root proliferation and extended lateral branching further highlight the effective nutrient uptake, reflecting the suitability and compatibility of aquaculture effluent in sustaining the growth of macrophytes [25].

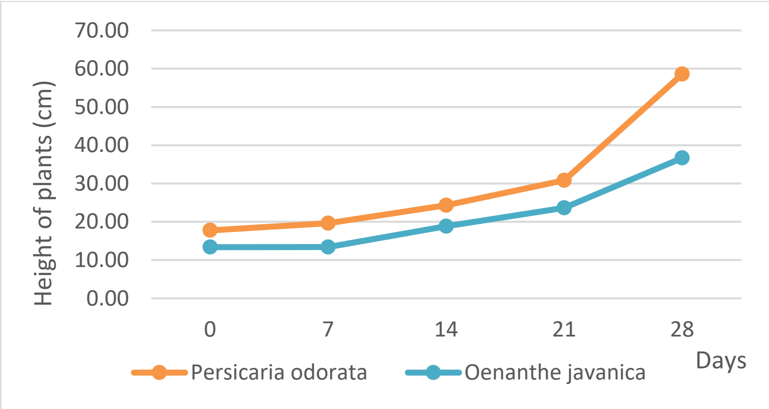


Figure 5: Height of plants against observation period.

4. CONCLUSION

This study successfully demonstrated the potential of both *Persicaria odorata* and *Oenanthe javanica* in aquaculture wastewater remediation, with *P. odorata* showing relatively higher effectiveness in both growth and pollutant removal. Specifically, *P. odorata* outperformed *O.javanica*, achieving significantly higher removal efficiencies for key pollutants like TAN, nitrate, and total dissolved solids (TDS). While both species effectively maintained most water quality parameters within the optimal range for aquaculture, a critical finding was that neither species reduced the Total Ammonia Nitrogen (TAN) concentration to below the water quality threshold by the Department of Environment, Malaysia. This research contributes new knowledge to the field by providing novel, comparative data establishing *P. odorata* as a viable and more effective plant species than the commonly studied *O. javanica* for nutrient reduction, thereby identifying an efficient, locally cultivated plant with high potential for developing more sustainable and ecologically sound biofiltration systems in aquaculture operations.

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