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Effectiveness of Mechanical and Chemical Filter Application on Water Quality, Phytoplankton, and The Emergence of Vibrio Bacteria in Intensive Shrimp Pond

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Abstract— **The aquaculture sector plays a crucial role in Indonesia's fisheries industry, especially with the rapid growth of *Litopenaeus vannamei* shrimp farming. However, intensive aquaculture systems face significant challenges, such as decreased water quality and increased Vibrio bacterial infections, which have the potential to cause diseases with high mortality rates. This study aimed to evaluate the effectiveness of mechanical and chemical filtration systems in improving pond water quality, maintaining phytoplankton balance, and suppressing pathogenic bacterial populations. This study was conducted for 30 days using a randomized group design (RAK) with three treatments, namely ponds without filtration (K), ponds with mechanical filtration (FF), and ponds with chemical filtration (FK). The results showed that chemical filtration was more effective in reducing total organic matter (TOM) and reducing Vibrio density to 1,740-1,880 CFU/mL. Meanwhile, mechanical filtration was more optimal in increasing the phytoplankton population to reach 123,000 ind/m^3. The application of the filtration system was also shown to increase dissolved oxygen (DO) levels and reduce total suspended solids (TSS), thus creating more stable water conditions for shrimp. The results of this study indicate that the implementation of an appropriate filtration system can be a strategic solution in supporting the sustainability of the *L. vannamei* aquaculture industry in Indonesia.**

Keywords— Aquaculture, chemical filtration, *L. vannamei*, mechanical filtration, Vibrio.

I. INTRODUCTION

Aquaculture has developed into the world's fastest-growing food production sector [1], recording an average annual increase of 9.58% in the period from 1990 to 2018 [2]. In 2018, total global aquaculture production reached 114.5 million tons in live weight, with an economic value that reached $263.6 billion [3]. This industry also has a crucial role in driving Indonesia's economic growth as a productive sector [4]. Indonesia is the second largest fish producer in the world after China, with production of capture and aquaculture fisheries, including aquatic plants, reaching around 6.5 million tons and 14.4 million tons in 2014 [5]. The fisheries sector has a strategic role in the national economy, contributing to income, job creation, provision of animal protein sources, and foreign exchange earnings [6; 7]. The fisheries sector plays an important role in the Indonesian economy, contributing around 21% to the total gross domestic product (GDP) in agriculture. In 2022, the contribution of this sector to the overall national GDP reached around 2.6% [8]. In addition, the fisheries sector provides about 6.4 million jobs, generates seafood export revenue of USD 4.86 billion, and fulfills 54.8% of people's animal protein needs [9].

The aquaculture sector in Indonesia has experienced rapid growth [5]. Although the majority of fish supply still comes from capture fisheries in marine and inland waters, the amount of fish catch has tended to stabilize in the past decade [10; 11]. This condition makes aquaculture the main sector driving the growth of fish production in Indonesia. Since 1960, the aquaculture industry has grown at an average annual growth rate of 7.7%, with the proportion of farmed fish increasing from 10.6% of total production in 1960 to 40.2% in 2014 [1]. Its rich natural resources cover more than 17,000 islands and 81,000 km of coastline [12; 13]. Indonesia has great potential to expand the aquaculture sector, one of which is shrimp farming [14].

In the aquaculture industry, shrimp farming is experiencing rapid growth at the global level, while natural shrimp catches tend to remain stable [15]. Among the various shrimp species contributing to this trend, *Litopenaeus vannamei* is the most dominant [16], with global production increasing dramatically from 155,000 tons in 2000 to 5.8 million tons in 2020. In contrast, *Penaeus monodon*, which previously dominated the industry, showed only a slight increase in production, from 631,000 tons in 2000 to 717,000 tons in 2020. Since being recorded in national statistics in 2004, vannamei shrimp farming in Indonesia has grown rapidly. In 2007, vannamei shrimp production surpassed that of *P. monodon* shrimp. Until 2020, vannamei shrimp production experienced a significant surge, reaching 722

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thousand tons, or 2.5 times more than *P. monodon* shrimp production. Although *P. monodon* shrimp also showed increased production, the growth was relatively slower, with total production reaching 208 thousand tons in 2020, an increase of about 58% compared to 2004 [17; 18].

The emergence of diseases caused by bacteria, especially from the genus Vibrio, is a significant challenge in maintaining the stability of shrimp production [19; 20]; 21]. Infections caused by Vibrio can result in very high mortality rates, even reaching 100% in aquatic organisms [22]. Given this sector's importance in the fisheries industry's sustainability, implementing optimal health management strategies in the larval culture and breeding process is crucial. Several Vibrio species, such as *V. harveyi*, *V. parahaemolyticus*, *V. alginolyticus*, and *V. cholerae*, are known to act as pathogens that hurt shrimp breeding programs [23]. In addition to threatening shrimp production, these bacteria also contribute to the spread of pathogens through the environment, which ultimately worsens disease outbreaks [17].

V. parahaemolyticus is the primary cause of Acute Hepatopancreatic Necrosis Disease (AHPND) [24; 25; 26]. The spread of this disease is further exacerbated by environmental conditions, especially the decline in water quality, which often occurs due to intensive farming systems. These practices increase the accumulation of excess nutrients, thus creating an environment that supports the growth of pathogens [27; 28]. Economically, the impact of this disease with estimated losses to the shrimp industry -0reaching more than USD 1 billion per year [29; 30].

The filtration system functions to pass water through a filter media before it is used in cultivation activities [31; 32]. Optimizing the use of this system is expected to maintain water quality sustainably, especially in terms of the balance of composition and density of microorganisms [33]. The main role of filtration systems is to maintain water quality by removing contaminants and improving environmental conditions for shrimp farming [34]. The filtration process aims to filter organic material, and in aquaculture, several types of filtration are commonly used, such as mechanical and chemical filtration. Mechanical filtration works to filter out large particles, including feed residue, feces, and detritus, while chemical filtration works to remove harmful chemicals in water. Filters that are still commonly used are aquaponic systems [35] and recirculating aquaculture systems (RAS) [36]. To the best of our knowledge, the use of mechanical and chemical filters in the intensive cultivation of L. vannamei is still rare. The effect of different filtration on the density of Vibrio parahaemolyticus and Vibrio harveyi has also not been studied. This is very important to increase the productivity of *L. vannamei* and prevent disease. This study used two different types of filters to evaluate their impact on pond water quality, which can directly affect the survival rate of aquaculture organisms [37]. Therefore, this study aimed to analyze how variations in filtration systems affect water quality, phytoplankton dynamics, and the presence of Vibrio bacteria in intensive shrimp ponds.

II. METHOD

This study was conducted for 30 days in May 2024. The sample analysis was conducted in the Faculty of Fisheries and Marine Sciences laboratory at Brawijaya University. This study used a randomized block design (RAK) method of three treatments with three replications. Sampling was carried out at three different locations, namely the entry, midpoint, and exit points, each repeated three times.

A : Pond treatment with mechanical filtration
B : Pond without treatment
C : Pond treatment with chemical filtration

Samples were taken from three locations: the inlet area, the middle section, and the outlet area. This study was conducted through four main stages: preparation of the filtration process, water sampling, bacterial culture analysis, and water quality evaluation. The mechanical filter system consists of three sequential layers: sponge, fiber, and sand (Figure 1). Meanwhile, chemical filtration consists of two layers: zeolite and charcoal or activated carbon (Figure 2). Both filtration systems are placed at the pool's inlet, so the incoming water will go through a filtration process before reaching the main pool.

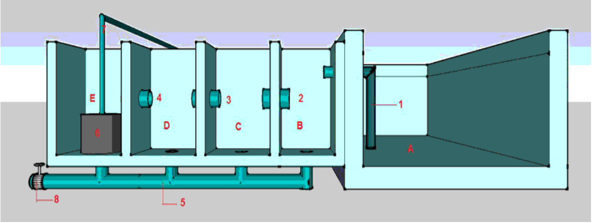

Figure 1. Illustration of mechanical filtration design. (A) Pond; (B) Sponge; (C) Fiber; (D) Sand; (E) Water pump; (1 – 4) Water pipe; (5) Outlet pipe; (6) Pump; (7) Inlet pipe; (8) Outlet water tap.

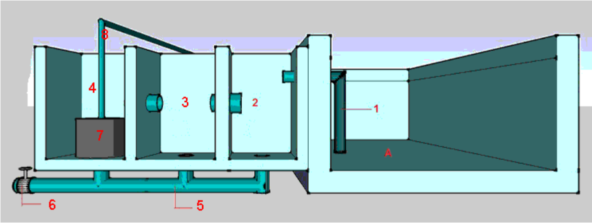

Figure 2. Illustration of chemical filtration design. (1) Inlet pipe; (2) Zeolite; (3) Charcoal; (4) Water pump room; (5) Outlet pipe; (6) Water outlet tap; (7) Water pump; (A) Pool.

Bacterial culture was carried out as done by Alfiansah [27] using a marine agar (MA) medium. Making MA began by dissolving 11.05 g of media powder in 200 mL of aquadest in an Erlenmeyer flask. The solution was then homogenized using a magnetic stirrer on a hot plate until it reached boiling point. The mouth of the Erlenmeyer flask was covered with aluminum foil, tied with a rubber band, then put into heat-resistant plastic. After that, the media was sterilized using an autoclave at a temperature of 121°C for 15 minutes. After sterilization, the press was cooled until the temperature dropped, then poured aseptically into a petri dish. Meanwhile, the selective medium for Vibrio culture used thiosulfate citrate bile salt sucrose (TCBS). It began by dissolving 17.816 g of media powder in 200 mL of aquadest in an Erlenmeyer flask. The solution was then homogenized using a magnetic stirrer on a hot plate until it boiled. The mouth of the Erlenmeyer flask is covered with aluminum foil and tied with a rubber band. After homogenization, the media solution is cooled to a temperature of 0.5°C before being poured aseptically into a petri dish. After both media have hardened, the petri dish is inverted and stored in a refrigerator or incubator at a temperature below 28°C to maintain the hardness of the media.

Water samples for Vibrio analysis were collected once a month at 07.00 to 11.00 WIB using sterile sample bottles with a capacity of 50 mL, then stored in a cool box to maintain sample quality. 50 µL of water was planted using the pour plate method on TCBS and MA media. After that, the petri dish was covered with plastic wrap to prevent external contamination and incubated for 24 hours at 37°C. The bacterial colonies were calculated using the total plate count (TPC) method. Meanwhile, water sampling for phytoplankton was carried out directly from the pond using a 20 L water basket. The collected water was filtered using a plankton net before being transferred into a 50 mL sample bottle. Water samples were given 2 to 3 drops of 4% formalin for preservation. A total of 10 water quality parameters were analyzed in this study, including temperature, pH, dissolved oxygen (DO), nitrate, phosphate, ammonia, brightness level, total organic matter (TOM), and total suspended solids (TSS).

III. RESULTS AND DISCUSSION

The results of the study showed that the application of mechanical and chemical filters in intensive shrimp farming systems had a significant impact on water quality. Based on the results of the study, the pond without a filter (K) had a pH of 8.3, while the pond using a mechanical filter (FF) and a chemical filter (FK) showed a higher pH, which was 8.5. In addition, dissolved oxygen (DO) levels increased from 7.8 mg/L in pond K to 8.2 mg/L in FF and 8.5 mg/L in FK, indicating more optimal oxygenation conditions. The highest total organic matter (TOM) content was recorded in pond K with a value of 94.3 mg/L, while in FF, there was a decrease to 90 mg/L, and FK experienced the most significant reduction to 60.8 mg/L. This indicates that chemical filters are more effective in reducing organic matter in water. On the other hand, the total suspended solids (TSS) initially high in pond K (83–83.5 mg/L) decreased to 43–44 mg/L in FF and 50–51 mg/L in FK. This finding indicates that the mechanical filter is more efficient in filtering suspended particles (Table 1). The resulting improvement in water quality also affects the pond ecosystem, especially in reducing the potential for Vibrio bacteria growth (Table 2). Chemical filters, which are more effective in lowering TOM content, play an essential role in suppressing the population of pathogenic bacteria. Meanwhile, mechanical filters increase water clarity, thus supporting the balance of phytoplankton in the pond environment

TABLE 1.
RESULTS OF WATER QUALITY MEASUREMENTS IN INTENSIVE *L. VANNAMEI* PONDS

Sampling Point	**pH**	**DO (mg/L)**	**TOM (mg/L)**	**TSS (mg/L)**
Inlet K	8.3	7.8	94.3	83
Center K	8.3	7.8	94.3	83.5
Fluid K	8.3	7.8	94.3	83.5
Inlet FF	8.5	8.2	90	44
Center FF	8.5	8.2	90	43
Fluid FF	8.5	8.2	90	43
Inlet FK	8.5	8.5	60.8	50
Center FK	8.5	8.5	60.8	51
Fluid FK	8.5	8.5	60.8	51

Not: K = Pool without filter; FF = Pool with mechanical filter; FK = Pool with chemical filter

Chemical filtration systems function to remove organic substances in water through mechanisms such as adsorption, oxidation, ion exchange, or coagulation [38; 39]. Activated carbon captures organic molecules in its pores, effectively reducing dissolved organic matter content, eliminating odors, and neutralizing toxins. Meanwhile, the oxidation method uses ozone, chlorine, or hydrogen peroxide agents to decompose complex organic compounds into more straightforward and less harmful forms. Advanced oxidation processes (AOP) combine UV light and these oxidants to increase decomposition efficiency. Ion exchange resins play a role in replacing unwanted organic ions with other more desirable ions, which are often applied to remove organic acids and other dissolved substances.

Chemical reactions, such as coagulation and oxidation, play a role in increasing the filtration system's effectiveness. Coagulation works by collecting fine particles, including organic compounds, to form larger aggregates that are easier to filter in the next stage [40]. Meanwhile, chemical oxidation, such as ozonation, decomposes complex organic molecules into more straightforward and less harmful compounds, which are easier to remove through filtration [41]. Research conducted by Michael-Kordatou [42] and Moona [39] showed that biologically activated carbon filters can effectively remove dissolved organic matter (DOM), which consists of organic matter that passes through a 0.45 μm filter, including humic acid and dissolved microbial products.

The mechanical filtration system increases water clarity and maintains the balance of phytoplankton populations in *L. vannamei* cultivation ponds by removing suspended solids, leftover feed, and organic materials that can cloud the water and disrupt ecosystem stability. By filtering fine particles, this filtration prevents the accumulation of excess sediment that can cause decreased oxygen levels and the accumulation of harmful gases. More transparent water allows deeper sunlight penetration, thus supporting healthy phytoplankton growth while inhibiting algal blooms that can trigger fluctuations in oxygen levels and pH instability [43]. In addition, mechanical filtration also plays a role in controlling nutrient levels by reducing the decomposition of organic matter, preventing the proliferation of harmful algae, and maintaining the stability of the aquatic environment [44; 45]. By improving overall water quality, this method creates optimal conditions for shrimp health, reduces stress levels, and supports better growth.

The results also showed that pond K had a lower phytoplankton density (27,300–30,500 ind/m³) and the highest number of Vibrio (3,964–4,230 CFU/mL). Pond FF increased phytoplankton density (116,700–123,000 ind/m³) and reduced Vibrio (2,300–2,720 CFU/mL), contributing to increased productivity of the pond ecosystem. Meanwhile, pond FK reduced the Vibrio population most effectively (1,740–1,880 CFU/mL), although its phytoplankton density was slightly lower (88,700–91,600 ind/m³). Mechanical filters were more effective in supporting the growth of phytoplankton as natural food, while chemical filters were more optimal in reducing pathogenic bacteria (Table 2).

TABLE 2.
RESULTS OF OBSERVATIONS OF PLANKTON AND VIBRIO DENSITIES IN INTENSIVE L. VANNAMEI PONDS

Sampling Point	**Plankton Density (Ind/m^3)**	**Total Vibrio (CFU/mL)**
Inlet K	27300	4111
Center K	30500	4230
Wheel K	29700	3964
Inlet FF	121300	2300
Center FF	116700	2720
Wheel FF	123000	2400
Inlet FK	88700	1830
Center FK	91600	1880
Wheel FK	90200	1740

Not: K = Pool without filter; FF = Pool with mechanical filter; FK = Pool with chemical filter

Mechanical filters play a role in removing excess organic material, unconsumed food residues, and suspended particles, thus increasing water clarity and allowing more sunlight to penetrate the water column. This increased light exposure supports the process of photosynthesis, thereby increasing phytoplankton density. Sumini & Kusdarwati [46] also showed that by reducing the accumulation of organic matter and excess nutrients such as ammonia and nitrite, mechanical filtration helps prevent conditions supporting Vibrio's growth. Phytoplankton have a crucial role in maintaining ecosystem balance by competing for nutrients that are also needed by Vibrio and producing natural antibacterial compounds that inhibit the development of these bacteria. In addition, abundant phytoplankton increases dissolved oxygen levels through photosynthesis, creating an oxygen-rich environment [47]. These conditions are less supportive of the development of Vibrio, which thrives more easily in environments with low oxygen levels. Mechanical filtration of organic matter also limits the availability of substrates that Vibrio can use to colonize, thereby reducing the population of these bacteria in the aquatic ecosystem [48]. In addition, some types of phytoplankton produce metabolites that can inhibit the growth of pathogenic bacteria, including Vibrio. This biological control mechanism plays a vital role in aquaculture systems, not only because it supports the nutritional needs of shrimp but also because it helps create a more balanced and healthy microbial community in the pond [49].

Research conducted by Rahmawati [50] also showed that the application of hydrocyclone mechanical filters in recirculating aquaculture systems (RAS) proved effective in improving water quality by removing suspended particles, thereby contributing to increased growth of various aquatic species, including shrimp. In addition, mechanical filtration systems can be combined with biological filtration methods to produce a more comprehensive water treatment solution, allowing for water reuse while reducing negative environmental impacts [51]. Tawfik [52] also showed that Showing improvements in water quality parameters, such as higher dissolved oxygen (DO) levels, balanced pH, and reduced ionized ammonia (NH_3) concentrations.

Chemical filters absorb substances, exchange ions, and trigger oxidation-reduction or catalytic reactions. This study shows that chemical filters can suppress the population of Vibrio bacteria because they eliminate organic matter and essential nutrients that support bacterial growth and directly disrupt their cell structure. Activated carbon plays a role in absorbing dissolved organic compounds, inhibiting Vibrio's access to the nutrients it needs. Meanwhile, oxidizing agents such as ozone, chlorine, and potassium permanganate damage bacterial cell membranes and destroy biofilms, making it more difficult for Vibrio to survive. Zeolite effectively removes ammonia and nitrogen compounds that support bacterial metabolism, thus further limiting their development. Chemical filters that are oxidizing also produce reactive oxygen species (ROS) that attack bacterial DNA, proteins, and enzymes, preventing Vibrio from reproducing. Combining these mechanisms, ranging from nutrient removal, membrane destruction, biofilm degradation, and oxidative inactivation, makes chemical filters superior to mechanical filters in controlling bacteria.

IV. CONCLUSION

Applying filtration systems in intensive shrimp ponds is essential in improving water quality and controlling the presence of pathogenic bacteria. Using mechanical filters contributes to water clarity and supports phytoplankton growth as a natural food source. Meanwhile, chemical filters are more effective in reducing the accumulation of organic matter and suppressing the population of Vibrio bacteria. The study results showed that the combination of filtration methods increased dissolved oxygen levels, reduced the concentration of organic matter, and reduced the population of pathogenic bacteria. Thus, an optimally applied filtration system can create a healthier cultivation environment and support the optimal growth of *L. vannamei* shrimp.

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