

The Effect of Total Suspended Solids on Phytoplankton Abundance and Water Quality Dynamics in Intensive Shrimp Ponds in Kraksaan, Probolinggo, Indonesia

Pengaruh Nilai Padatan Tersuspensi terhadap Kelimpahan Fitoplankton dan Dinamika Kualitas Air pada Tambak Udang Intensif di Kraksaan, Probolinggo, Indonesia

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Abstract. Intensive cultivation of whiteleg shrimp (*Litopenaeus vannamei*) has the potential to increase suspended solids concentrations, which can affect water quality and phytoplankton community structure. This study aims to analyze the effect of reducing Total Suspended Solids (TSS) concentrations through the application of a filtration system on phytoplankton abundance and water quality dynamics in intensive ponds. The study was conducted in intensive shrimp ponds in Kraksaan District, Probolinggo Regency, East Java, using an observational-experimental approach comparing pond conditions without filtration, mechanical filtration, and chemical filtration. The parameters observed included TSS, phytoplankton abundance, and several water quality parameters such as temperature, clarity, pH, dissolved oxygen (DO), salinity, nitrate, and orthophosphate. The results showed that mechanical filtration was able to reduce TSS most effectively with a range of 38–47 mg/L compared to chemical filtration (57–63 mg/L) and without filtration (81–91 mg/L). The decrease in TSS was followed by an increase in water clarity and DO concentration. The highest phytoplankton abundance was found in the mechanical filtration treatment (2,870–3,084 ind/L), followed by chemical filtration (2,121–2,291 ind/L), while without filtration showed the lowest abundance (1,062–1,401 ind/L). These results indicate that reducing TSS through the filtration system increases light penetration, thus supporting phytoplankton photosynthetic activity. Overall, the application of filtration systems, especially mechanical filtration, plays an important role in improving water quality and increasing phytoplankton productivity, thus potentially supporting ecosystem stability and the sustainability of intensive vannamei shrimp farming systems.

Keywords: mechanical filtration, chemical filtration, phytoplankton, *Litopenaeus vannamei*, total suspended solids.

Abstrak. Budidaya udang vannamei (*Litopenaeus vannamei*) secara intensif berpotensi menimbulkan peningkatan konsentrasi padatan tersuspensi yang dapat memengaruhi kualitas air dan struktur komunitas fitoplankton. Penelitian ini bertujuan untuk menganalisis pengaruh penurunan konsentrasi Total Suspended Solids (TSS) melalui penerapan sistem filtrasi terhadap kelimpahan fitoplankton dan dinamika kualitas air pada tambak intensif. Penelitian dilakukan di tambak udang intensif di Kecamatan Kraksaan, Kabupaten Probolinggo, Jawa Timur dengan pendekatan observasional-eksperimental yaitu membandingkan kondisi tambak tanpa filtrasi, filtrasi mekanis, dan filtrasi kimia. Parameter yang diamati meliputi TSS, kelimpahan fitoplankton, serta beberapa parameter kualitas air seperti suhu, kecerahan, pH, oksigen terlarut (DO), salinitas, nitrat, dan ortofosfat. Hasil penelitian menunjukkan bahwa filtrasi mekanis mampu menurunkan TSS paling efektif dengan kisaran 38–47 mg/L dibandingkan filtrasi kimia (57–63 mg/L) dan tanpa filtrasi (81–91 mg/L). Penurunan TSS tersebut diikuti oleh peningkatan kecerahan perairan dan konsentrasi DO. Kelimpahan fitoplankton tertinggi ditemukan pada perlakuan filtrasi mekanis (2.870–3.084 ind/L), diikuti filtrasi kimia (2.121–2.291 ind/L), sedangkan tanpa filtrasi menunjukkan kelimpahan terendah (1.062–1.401 ind/L). Hasil ini menunjukkan bahwa penurunan TSS melalui sistem filtrasi meningkatkan penetrasi cahaya sehingga mendukung aktivitas fotosintesis fitoplankton. Secara keseluruhan, penerapan sistem filtrasi, khususnya filtrasi mekanis, berperan penting dalam memperbaiki kualitas air dan meningkatkan produktivitas fitoplankton, sehingga berpotensi mendukung stabilitas ekosistem dan keberlanjutan sistem budidaya udang vannamei intensif.

Kata Kunci: filtrasi kimia, filtrasi mekanis, fitoplankton, *Litopenaeus vannamei*, total padatan tersuspensi.

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INTRODUCTION

Intensive cultivation of whiteleg shrimp (*Litopenaeus vannamei*) is a fisheries subsector that plays a strategic role in supporting the increase of national production and exports. The application of intensive farming systems through high stocking densities and the use of artificial feed has been proven to increase pond productivity. However, these practices also have the potential to exert pressure on aquatic environmental quality. Various studies have confirmed that water quality is a determining factor in the success of intensive shrimp farming, as it directly affects shrimp growth, health, and survival rates. Therefore, optimal water quality management is a key prerequisite for achieving a productive and sustainable intensive shrimp farming system (Prastiwi et al., 2025; Shilman et al., 2025).

One parameter commonly used as an indicator for evaluating water quality is Total Suspended Solids (TSS). High TSS concentrations indicate a greater potential for water pollution and can inhibit light penetration into the water column, thereby reducing water clarity and disrupting the photosynthetic processes of aquatic organisms (Isman et al., 2022). Total Suspended Solids (TSS) are suspended materials in water consisting of mud particles, fine sand, organic matter, and microorganisms. High TSS concentrations can increase water turbidity, thereby reducing sunlight penetration and disrupting the photosynthetic processes of aquatic organisms (Fanela et al., 2019).

In the shrimp pond ecosystem, phytoplankton plays a fundamental role as a primary producer due to its ability to utilize light and dissolved nutrients to carry out photosynthesis, thus providing basic organic matter and dissolved oxygen, which are highly needed by aquatic organisms, including *Litopenaeus vannamei* (Takarina et al., 2020). In addition, phytoplankton plays an important role in the nutrient cycle, especially in the assimilation of nitrogen and phosphorus derived from feed residues and cultivation metabolites, thus contributing to the regulation of nutrient dynamics and the stability of pond water quality (Harliani et al., 2025). The abundance of phytoplankton is widely used as a biological indicator of water quality because these organisms are highly responsive to changes in environmental conditions, especially TSS fluctuations and nutrient availability (Harliani et al., 2025).

Filtration systems are a common method used to manage water quality in aquaculture. This process involves passing water through various filter media capable of adsorbing and removing pollutant particles. The use of appropriate filter media can help reduce suspended solids and organic matter and improve water quality, making it more suitable for supporting the life of cultivated organisms (Yustianti et al., 2024). Reducing TSS concentrations through the filtration process has the potential to increase light penetration in the pond water column, which in turn supports the photosynthesis process of phytoplankton (Hasanah et al., 2023). Improvements in the physical condition of these waters can influence the structure of phytoplankton abundance. Thus, changes in water quality due to reduced TSS trigger ecological responses in the phytoplankton community, allowing its community structure to reflect the ecological conditions and stability of the pond ecosystem as a whole. This study aims to analyze the effect of reducing Total Suspended Solids (TSS) concentrations through the implementation of a filtration system on phytoplankton abundance and water quality dynamics in supporting ecosystem stability and the sustainability of intensive shrimp farming systems.

MATERIAL AND METHODS

This research was conducted in whiteleg shrimp (*Litopenaeus vannamei*) ponds with an intensive cultivation system located in Kraksaan District, Probolinggo Regency, East Java. The study was conducted by observing conditions without a filtration system and with the use of a filtration system to reduce the concentration of Total Suspended Solids (TSS) in the cultivation media. The filtration methods used were mechanical and chemical filtration. Sampling in this study was conducted over four weeks, with sampling performed once a week from DOC 29 to DOC 47. The research approach used was observational-experimental, comparing water quality conditions and phytoplankton community structure in ponds without filtration and ponds using filtration. The filtration system used was mechanical filtration, utilizing layered filter media such as sand, gravel,

and synthetic fibers, which functioned to filter suspended particles in the water. Pond water was passed through filter media before being reused in cultivation activities, thus reducing the TSS concentration. Filtration effectiveness was evaluated based on changes in TSS values measured in ponds without filtration and ponds using the filtration system.

Sampling in this study was conducted in a structured manner to ensure the representativeness of the data obtained. Samples were collected from three ponds, each representing a different treatment. In each pond sample, sampling was carried out at three observation points determined based on the characteristics of the water flow, namely at the inlet (water inlet), outlet (water outlet), and the middle of the pond. The purpose of determining these points was to describe variations in water quality conditions throughout the pond as a whole. In addition, each sampling was repeated twice at each observation point. The collected water samples were used for TSS analysis and phytoplankton observations. TSS measurements were carried out using the gravimetric method by filtering water samples using filter paper with a specific pore size, after which the solid residue was dried and weighed to obtain the TSS value in mg/L units.

The phytoplankton sampling method in this study used the bucket method, namely by collecting water samples using a 5-liter bucket, repeated 10 times, which were then filtered using a plankton net with a mesh size of 25 µm. The filtered water was concentrated in a 50 mL collection bottle at the end of the plankton net. The obtained phytoplankton samples were then preserved using three drops of 5% Lugol's solution applied with a dropper and analyzed in the laboratory. Phytoplankton were identified using the Prescott and Davis book to determine up to the genus level. Phytoplankton abundance data analysis was calculated using the modified Luckey Drop method (Odum, 1993; Herawati et al., 2019) as follows:

$$N = \frac{T \times V}{L \times v \times p \times W} \times n \dots\dots\dots (1)$$

Description:

- N: Total Phytoplankton Count (ind/L)
- n: Number of plankton in each field of view
- T: Cover glass area (20x20 mm)
- L: Area of one field of view
- p: Number of fields of view observed
- v: Concentrated sample volume (mL)
- W: Filtered water volume (L)

In addition to TSS, measurements of supporting water quality parameters were carried out to strengthen the interpretation of the research results, including temperature, clarity, pH, dissolved oxygen (DO), nitrate, and orthophosphate. These parameters were measured in situ using standard measuring instruments for four weeks, with sampling intervals of once a week in each pond. The data obtained were analyzed descriptively and comparatively to determine differences in conditions between ponds without filtration and ponds with filtration. The relationship between TSS concentration and phytoplankton community structure was analyzed using correlation and simple regression analyses. The results are presented in tables and graphs to facilitate interpretation and discussion

RESULTS AND DISCUSSION

General Conditions of Intensive Shrimp Ponds

This research was conducted in whiteleg shrimp (*Litopenaeus vannamei*) ponds that implemented an intensive cultivation system with a stocking density of ±1,500,000 shrimp/ha. The feed dose given was generally in the range of 3-4% of biomass per day from DOC 29 to DOC 35 because the shrimp were still in the growth transition stage, while from DOC 36 to DOC 47 the feed dose was increased to ±4-4.5% of biomass along with the increasing appetite and growth rate of the shrimp. The determination of the feed dose remained dynamic and was adjusted based on the results of observations on the

ANCO (feeding tray). Characteristics of the cultivation system, such as the use of artificial feed, mechanical aeration, and water circulation management, are part of the intensive cultivation practices commonly applied in whiteleg shrimp (*Litopenaeus vannamei*) farming to maintain suitable environmental conditions throughout the shrimp rearing period (Akbarurrasyid et al., 2025). Water quality conditions under the system without filtration showed that most physical and chemical parameters were within the optimal range in accordance with Class 3 water quality standards intended for fisheries activities. However, the Total Suspended Solids (TSS) concentration was still relatively high, accompanied by a low level of water clarity, indicating the accumulation of suspended particles that have the potential to inhibit light penetration into the water column. This finding is consistent with other studies showing that water quality dynamic parameters, including suspended solids concentration, are important factors often associated with the performance and conditions of whiteleg shrimp (*Litopenaeus vannamei*) cultivation in intensive systems.

Changes in Total Suspended Solid (TSS) Concentration

The results of reducing Total Suspended Solids (TSS) levels through the application of different filtration methods are presented in Figure 1. Based on the graph, it can be seen that the treatment using a mechanical filter produced the lowest TSS value compared to the chemical filter treatment and the control treatment (without filtration). In ponds without a filtration system, TSS values ranged from 81-91 mg/L. Meanwhile, the use of mechanical filters reduced TSS values to 38-47 mg/L. In ponds using chemical filters, TSS values were recorded at 57-63 mg/L.

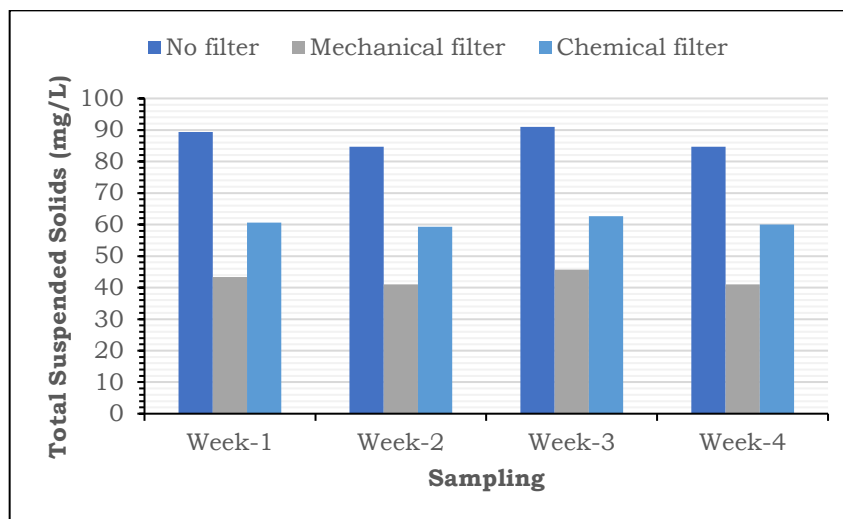


Figure 1. Total Suspended Solids (TSS)

Conditions without filtration did not provide a particle retention mechanism, causing suspended particles to remain in the water column and resulting in consistently high TSS values. The reduction in Total Suspended Solids (TSS) levels in treatments using a filtration system occurred due to the mechanism of retaining and reducing suspended particles in the water column. In mechanical filters, the most significant reduction in TSS occurred due to the physical filtration process, in which suspended solid particles were retained by the pores of the filtration media according to particle size, thus preventing them from being re-dispersed into the water. Furthermore, the continuous flow of water through the filter media also increased the opportunity for particle sedimentation through the micro-sedimentation mechanism. According to Khoiriyah (2024), The physical filtration process in porous media retained particles larger than the pore size, effectively reducing TSS, and, together with continuous water flow, increased the opportunity for micro-sedimentation.

Meanwhile, in chemical filters, TSS reduction occurred through coagulation and adsorption processes, in which suspended particles clumped or bound to the surface of the chemical media, thereby increasing their size and making them easier to settle.

However, the effectiveness of this mechanism was relatively lower compared to direct physical filtration, as reflected by the TSS values, which remained higher than those in mechanical filters. According to Pradelia et al. (2025), the reduction of TSS through chemical filtration can occur due to the coagulation-flocculation process, which destabilizes suspended particles and forms larger aggregates, making them easier to settle or be retained by the filtration media before discharge. However, its effectiveness is influenced by the type of coagulant, pH, and process conditions, so in some cases it remains less effective than direct physical filtration.

Filtration media play an important role in retaining suspended particles through physical filtration mechanisms and surface adsorption, where solid particles larger than the pores of the media are retained directly, while finer particles can be trapped within the media structure due to repeated contact with the filtration surface, thus contributing to a significant reduction in Total Suspended Solids (TSS) values (Hidayah et al., 2019). Differences in the characteristics of filtration media, especially pore size and specific surface area, affect the media's ability to retain suspended particles; thus, the smaller the pore size and the larger the surface area of the media, the higher the TSS removal efficiency tends to be (Sholihah et al., 2025).

Phytoplankton Analysis

Phytoplankton analysis is used to describe the ecological conditions of waters, revealing levels of productivity and nutrient availability. Based on the data on phytoplankton abundance in the treatment without filtration, values ranged between 1,062–1,401 ind/L (Figure 2). In the mechanical filtration treatment, phytoplankton abundance increased significantly, namely 2,870–3,084 ind/L, while in the chemical filtration treatment it ranged from 2,121–2,291 ind/L. Habibi (2020) stated that based on phytoplankton abundance, waters are divided into three categories: the range of 0–2,000 ind/mL is included in the oligotrophic or low abundance waters category; the range of 2,000–15,000 ind/mL is included in waters with moderate or mesotrophic plankton abundance; and the range >15,000 ind/mL is included in the eutrophic category with high plankton abundance. Reducing Total Suspended Solids (TSS) in water increases light penetration into the water column, expanding the euphotic zone and supporting phytoplankton photosynthesis. Biologically, increased light intensity allows photosynthetic phytoplankton to utilize light energy more optimally for primary production, thereby increasing their growth and abundance. In addition, reducing suspended particles also reduces the shading effect, making light distribution more even in the water column (Munru et al., 2023).

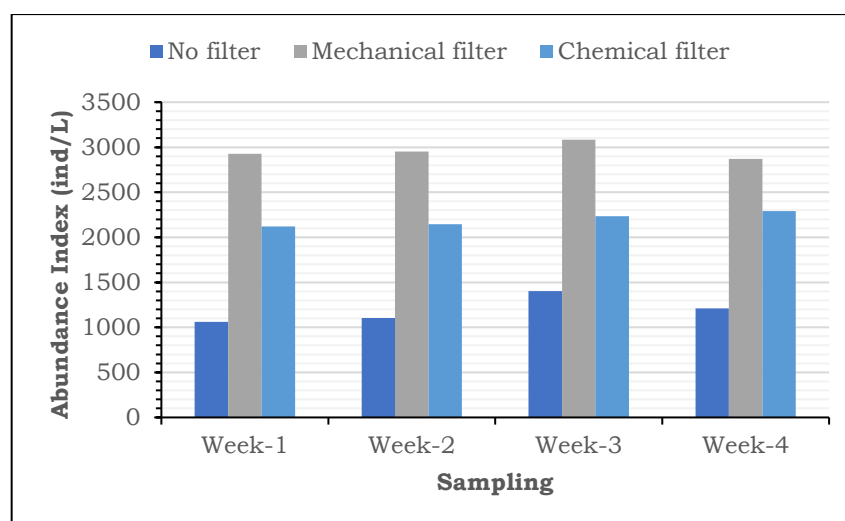


Figure 2. Phytoplankton Abundance Index

Overall, mechanical filtration showed the highest phytoplankton abundance compared to other treatments. This increase is thought to be related to a decrease in suspended particles, which increases water clarity and optimizes photosynthesis. Light

intensity and water temperature are known to have a strong correlation with phytoplankton abundance, with clearer waters tending to support higher primary productivity (Zainuri et al., 2023).

Changes in water turbidity affect community structure and interspecific competition patterns among phytoplankton. In waters with high TSS (turbidity), light penetration is limited, thereby limiting the presence of low-light-tolerant species. Conversely, when turbidity decreases and light penetration increases, competition shifts toward species that require higher light intensity for optimal photosynthesis. Increased light availability increases the photosynthetic efficiency of these groups, leading to increased abundance, while the dominance of turbidity-tolerant species potentially decreases. Thus, light intensity, influenced by turbidity levels, is a major controlling factor in the dynamics of competition and changes in phytoplankton community structure in aquaculture waters (Abdullah et al., 2025).

Dynamics of Water Quality Parameters

The dynamics of water quality parameters such as temperature, pH, salinity, dissolved oxygen (DO), and nutrients play a crucial role in controlling the balance of pond ecosystems and influencing the structure of phytoplankton communities (Figure 3). Fluctuations in these parameters due to intensive cultivation activities can alter the availability of light and nutrients, thus impacting the abundance, composition, and dominance of phytoplankton in cultured waters (Takarina et al., 2020).

Based on temperature data, pond temperature ranged between 27.1–29.0°C. The treatment without filtration showed the highest temperature in the second replication (29.0°C), while the mechanical and chemical filtration treatments tended to produce more stable temperatures, with ranges of 27.1–28.8°C and 27.2–28.5°C, respectively. Overall, all temperature values are still within the optimal range for intensive shrimp cultivation, so that differences in filtration treatment do not cause significant temperature changes but have the potential to suppress daily temperature fluctuations and maintain stable water conditions for organism metabolic activity and phytoplankton dynamics.

The water temperature of intensive shrimp ponds is reported to be in the range of 27–31°C and is still considered within the optimal limits to support the growth of whiteleg shrimp and maintain stable plankton abundance. Temperatures within this range play a role in controlling shrimp metabolic activity, phytoplankton photosynthesis processes, and other water quality dynamics, so temperature stability is an important factor in maintaining primary productivity and the performance of intensive shrimp farming (Aisyah et al., 2023). Water temperature is an important water quality parameter that affects the metabolic processes of cultured organisms and the dynamics of plankton communities, so its fluctuations can impact the balance of the pond ecosystem (Rizaldi et al., 2024).

In four replications, the highest brightness value was found in the mechanical filtration treatment with a range of 51–56 cm, followed by chemical filtration at 42–45 cm, while without filtration showed the lowest brightness at 30–36 cm. These results indicate that the filtration process, especially mechanical filtration, effectively increases water clarity by reducing the concentration of suspended particles (TSS), so that light penetration into the water column becomes more optimal. The decrease in TSS value is inversely proportional to the increase in brightness, because the fewer suspended particles, the greater the intensity of light that can penetrate the water. According to the opinion of (Herdianti et al., 2015), the increase in brightness has the potential to support phytoplankton photosynthesis activity and maintain the stability of water quality in intensive shrimp ponds because good brightness is related to primary productivity and the balance of the cultivated aquatic ecosystem.

Dissolved oxygen showed a range of 7.49–8.57 mg/L, with the highest value in mechanical filtration, followed by chemical filtration and without filtration. This indicates that reducing TSS through filtration can increase light penetration and stimulate phytoplankton photosynthesis, resulting in higher dissolved oxygen concentrations. The relatively high and stable DO conditions indicate an aquatic environment that supports

the respiration of cultured organisms and the balance of the pond ecosystem, in line with the opinion of [Mulatsih et al. \(2023\)](#) who stated that phytoplankton abundance plays an important role in increasing DO, while high TSS can inhibit light penetration and reduce oxygen production in the water. When dissolved oxygen is at an optimal level, the growth rate and survival of organisms may increase ([Anjasmara et al., 2025](#)).

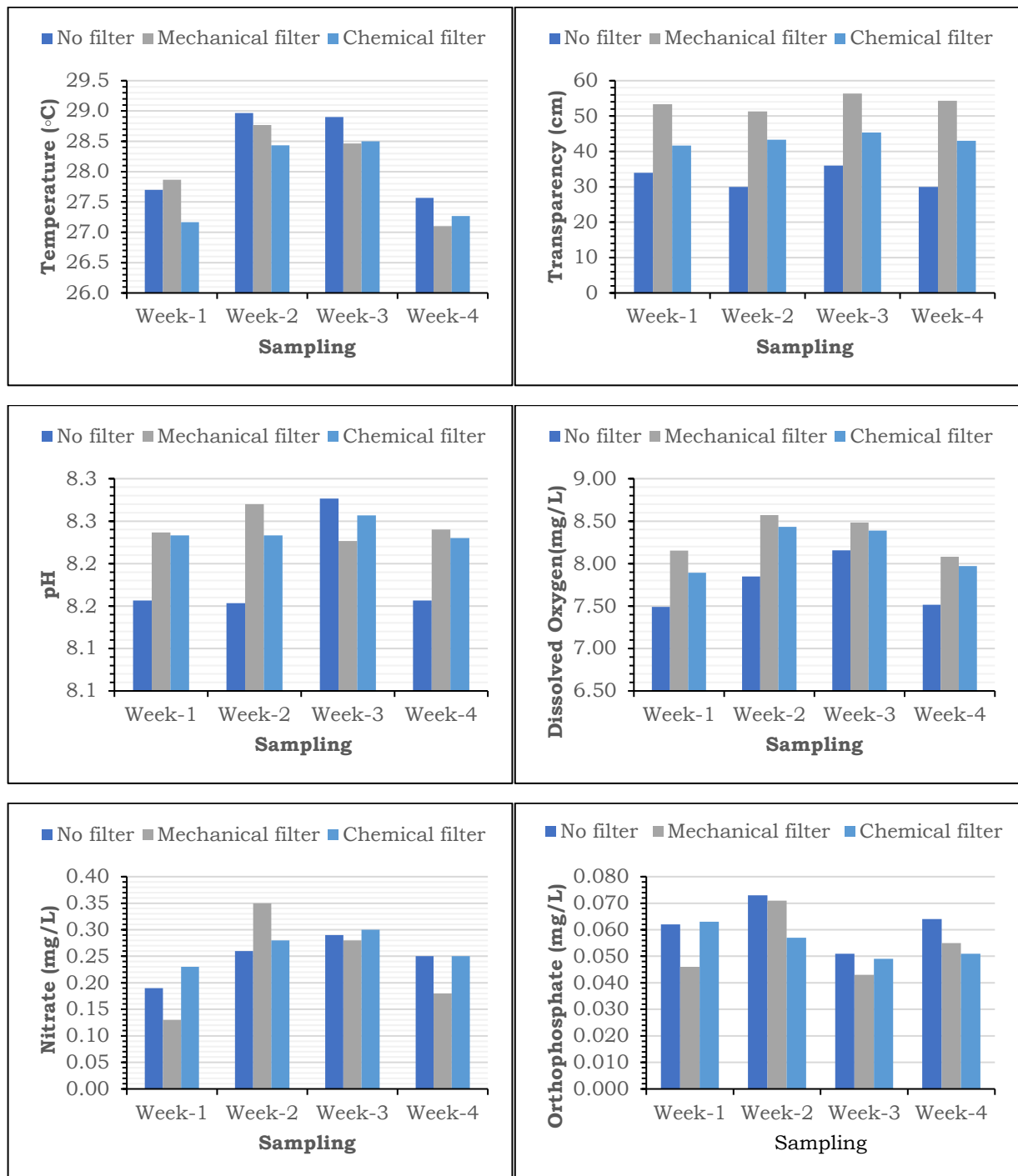


Figure 3. Water Quality

The pH is a crucial water quality parameter that must be maintained at optimal levels because it directly impacts the growth, reproduction, and survival of whiteleg shrimp in ponds. The pH values across the four replications were relatively stable across all treatments, ranging from 8.2 to 8.3. According to [Rahman et al. \(2016\)](#), the ideal pH range for aquatic organisms is between 6.5 and 8.5. Treatments without filtration, mechanical filtration, and chemical filtration showed very small differences, so the filtration process did not have a significant effect on changes in water pH. Overall, a

stable pH value indicates water conditions that support biological activity, while high daily pH fluctuations can cause stress to shrimp and disrupt the balance of the pond ecosystem. Therefore, stable pH management is essential for optimal shrimp growth and development in aquatic environments with neutral to slightly alkaline acidity (Riyadi & Liubana, 2025).

Salinity is a water quality parameter that greatly influences the survival of whiteleg shrimp fry because it is closely related to the organism's osmoregulatory ability. The salinity values in all filtration treatments showed uniform results, namely around 18 ppt in each repetition, so it can be concluded that the filtration process does not affect changes in the salinity of the cultivation media. This uniformity indicates that salinity is more influenced by the water source and water exchange management than by the suspended particle filtration (TSS) process. Salinities closer to optimal conditions result in higher fry survival rates, while salinities that are too low result in decreased survival because the shrimp must work harder to balance their body osmotic pressure with the aquatic environment (Ahmad et al., 2023).

Nitrate concentrations across all treatments ranged from 0.13–0.35 mg/L, with relatively small fluctuations between filtration runs. According to Prasetiyono et al. (2022), the optimal nitrate range in ponds is generally within ± 0.1 –1 mg/L, as it still supports primary productivity without triggering excessive eutrophication. Filtration, particularly mechanical filtration, is thought to reduce TSS, thereby improving water clarity and light penetration, which in turn supports nitrate utilization by phytoplankton for photosynthesis. With reduced suspended particles, available nutrients such as nitrate are more effectively utilized by phytoplankton, thus contributing to increased primary productivity and stable pond water quality. This shows that TSS management through a filtration system plays an important role in regulating nutrient dynamics and phytoplankton growth in aquaculture waters. Reducing TSS through filtration improves water clarity and light penetration, thus optimizing nitrate utilization by phytoplankton. Therefore, TSS management through filtration plays a crucial role in regulating nutrient dynamics, phytoplankton growth, and maintaining stable water quality in intensive shrimp ponds (Rohani et al., 2016).

Based on the data in the figure, the orthophosphate concentration in the treatment without filtration ranged from 0.051–0.073 mg/L with an average value of around 0.063 mg/L. After mechanical filtration, the concentration decreased to 0.043–0.071 mg/L with an average of around 0.054 mg/L. Meanwhile, chemical filtration showed a range of 0.049–0.063 mg/L with an average value of around 0.055 mg/L. This is in line with research results, which show that phosphate concentrations in productive pond waters are generally in the range of 0.02–0.1 mg/L, which are still able to support phytoplankton growth without causing excessive eutrophication (Prasetiyono et al., 2022).

These results indicate that both filtration methods are able to reduce orthophosphate concentrations compared to no filtration, with mechanical filtration being slightly more effective based on the lowest average value. The reduction in orthophosphate levels through mechanical filtration occurs due to the process of removing suspended particles that bind phosphate, while chemical filtration works through adsorption or precipitation mechanisms using certain media. This is in line with the opinion of Edwin et al. (2025), which shows that the use of filtration media such as biochar is able to remove phosphate and other contaminants from wastewater, improving water quality through adsorption and extended contact between water and filtration media.

CONCLUSION

The application of a filtration system in intensive whiteleg shrimp (*Litopenaeus vannamei*) ponds has been proven to reduce the concentration of Total Suspended Solids (TSS) and improve pond water quality conditions. Mechanical filtration showed the highest effectiveness in reducing TSS values, ranging from 38–47 mg/L, followed by chemical filtration at 57–63 mg/L and without filtration at 81–91 mg/L. The decrease in TSS concentration was followed by an increase in water clarity and higher and more

stable dissolved oxygen (DO) conditions. The highest phytoplankton abundance was found in the mechanical filtration treatment with a range of 2,870–3,084 ind/L, followed by chemical filtration at 2,121–2,291 ind/L, while without filtration showed the lowest abundance at 1,062–1,401 ind/L. Overall, the results of this study indicate that reducing TSS through filtration systems, especially mechanical filtration, contributes positively to improving water quality and increasing phytoplankton productivity in intensive shrimp ponds.

AUTHOR CONTRIBUTIONS STATEMENT

The authors declare that the contribution of each author to the preparation of this paper is as follows: CL played the main role in developing the research concept, generating the initial idea, and writing the first draft of the manuscript. ASA contributed to the design of the research methodology, development of the research instruments, and correspondence with the journal. IF conducted field data collection and documented the research activities. HP was responsible for data analysis and statistical processing. DA performed data validation and verification of the research findings. AWP contributed to the interpretation of the results and the preparation of the discussion section. AY was responsible for data visualization, including tables, graphs, and figures. AFT supervised the study and oversaw the overall research process. SDN was responsible for the final review and editing of the manuscript. FIH assisted in designing the research methodology. The authors have attached a letter of author declaration.

CONFLICT OF INTEREST STATEMENT

The author has declared that there is no conflict of interest with any party regarding the publication of this article.

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