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Phytoremediation for Nutrient Removal in an Environmentally Friendly Floating Cage System: A Field Experiment

(Fitoremediasi untuk Penyingkiran Nutrien dalam Sistem Sangkar Terapung Mesra Alam: Suatu Uji Kaji Lapangan)

LISMINING PUJIYANI ASTUTI[1,*], ANDRI WARSA[1], AGUS ARIFIN SENTOSA[2], DIDIK WAHJU HENDRO TJAHJO[1] & TARZAN SEMBIRING[3,4,5]

[1]Research Center for Conservation of Marine and Inland Water Resources, Cibinong Science Center, Jl. Jakarta-Bogor Km 48 Cibinong, West Java, Indonesia 16911
[2]Research Institute for Fish Resource Enhancement, Jalan Cilalawi No. 1, Jatiluhur, Purwakarta, West Java, Indonesia 41152
[3]Research Center for Environmental and Clean Technology, Jl. Cisitu lama 21/154 D, Bandung, West Java – Indonesia 40135
[4]Faculty of Medicine, University of Malahayati Jl. Pramuka No.27, Kemiling Permai, Kec. Kemiling, Kota Bandar Lampung, Lampung, Indonesia
[5]Colaborative Research Center of Zero Waste and Sustainability. Widya Mandala Catholic University, Surabaya. Jl. Kalijudan 37 Surabaya, 60114, Indonesia

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ABSTRACT

Aquaculture is one of the efforts to optimize the utilization of water bodies. Aquaculture using floating net cages is detrimental to water, namely causing pollution from uneaten feed and fish excretion. Water quality would be degraded due to eutrophication, oxygen depletion, and uncontrolled growth of algae and aquatic plants. High concentrations of nitrogen and phosphorus mainly trigger water quality degradation and eutrophication. To reduce the negative impact of aquaculture activities in floating net cages in reservoir/lake waters, an environmentally friendly cage technology that is low waste is needed. The technology offered is a loop bio-phytoremediation system equipped with floating net cages, a water management system with recirculation, and plants. The floating net cage used is a double net where the upper net consists of two nets and a bottom net. The upper net is used for rearing carp fish, and the bottom net for tilapia. The plants used as phytoremediation agents were water spinach and vetiver grass. Moreover, the physical filter used for processed water before recirculating to the waterbody in the FNC consists of sand, palm fiber, and limestone layers. The results showed that the effectiveness of nutrient removal on water spinach hydroponic (HRT=15 h), vetiver grass wetland (HRT=36 h), and physical filters (HRT=2,4 h) in reducing nitrate was 83%, 86%, and 67%, respectively; maximal reduction of the organic matter reached 94%, 96%, and 96%, respectively; as well as the highest reduction in total phosphorus was 78%, 89%, and 82%, respectively.

Keywords: Environmentally friendly floating net cages; loop bio-phytoremediation system; phytoremediation agent; the removal of nutrient

ABSTRAK

Akuakultur adalah salah satu usaha untuk mengoptimumkan pemanfaatan badan air. Akuakultur menggunakan sangkar pukat apung menyebabkan impak negatif kepada air iaitu pencemaran yang berpunca daripada makanan yang tidak dimakan dan perkumuhan ikan. Kualiti air akan merosot disebabkan oleh eutrofikasi, kekurangan oksigen dan pertumbuhan alga dan tumbuhan akuatik yang tidak terkawal. Kemerosotan kualiti air dan eutrofikasi terutamanya dicetuskan oleh kehadiran kepekatan tinggi nitrogen dan fosforus. Bagi mengurangkan kesan negatif aktiviti akuakultur dalam sangkar jaring terapung di perairan takungan/tasik, teknologi sangkar mesra alam yang mempunyai sisa rendah diperlukan. Teknologi yang ditawarkan ialah sistem bio-fitoremediasi gelung yang dilengkapi dengan sangkar jaring terapung, sistem pengurusan air dengan peredaran semula dan tumbuhan. Sangkar jaring terapung yang digunakan ialah jaring berganda dengan jaring atas terdiri daripada dua jaring dan jaring bawah. Jaring atas digunakan untuk menternak ikan kap dan jaring bawah untuk ikan tilapia. Tumbuhan yang digunakan sebagai agen fitoremediasi ialah bayam air dan rumput vetiver. Penapis fizikal digunakan untuk memproses air sebelum diedarkan semula ke badan air dalam sangkar pukat ikan yang terdiri daripada pasir, sabut kelapa sawit dan lapisan batu kapur: Hasil kajian menunjukkan bahawa keberkesanan penyingkiran nutrien pada hidroponik bayam air (HRT=15 jam), tanah lembap rumput vetiver (HRT=36 jam) dan penapis fizikal (HRT=2.4 jam) dalam mengurangkan nitrat masing-masing adalah 83%, 86% dan 67%; pengurangan maksimum bahan organik masing-masing mencapai 94%, 96% dan 96%; serta pengurangan tertinggi dalam jumlah fosforus masing-masing ialah 78%, 89% dan 82%.

Kata kunci: Agen fitoremediasi; bio-fitoremediasi gelung; penyingkiran nutrien; sangkar jaring terapung mesra alam

Introduction

Fisheries activities, both capture and aquaculture fisheries, are mainly carried out in reservoirs and lakes. The developing aquaculture activity is aquaculture using floating net cages (FNC). However, this activity has a negative impact, namely water quality degradation, such as eutrophication, oxygen depletion, and uncontrolled growth of algae and aquatic plants. Jatiluhur Reservoir, for example, is one reservoir with a massive quantity of floating net cages. This activity has affected the water quality, which has worsened over time. The trophic status of Jatiluhur Reservoir is at the level of eutrophic-hypertrophic (Astuti et al. 2022).

The problem with aquaculture by floating net cages is that the uneaten feed is partially decomposed in the waters. A study by Syafitrianto (2015) states that uneaten feed and excretion of fishes are in the form of nitrogen (N) and phosphorus (P) compounds. Nitrogen and phosphorus are nutrients that cause eutrophication, characterized by blooming algae and aquatic plants. When discharged into the water column and not utilized by organisms around the lake, such as fish and benthic organisms, it will become suspended in colloidal particles at the bottom of the water. About 20-30% of the feed will be uneaten and wasted in the waters from the current FNC system (Krismono & Wahyudi 2001), so it can be a source of nitrogen, phosphorus, and organic matter pollution. The incompletely decomposed organic matter from uneaten feed will cause an enrichment of nutrients in the form of nitrate and phosphate in the waters (Sugiarni, Arthana & Kartika 2019). Therefore, we need an environmentally friendly cultivation technology that can reduce nutrients (N and P) loading into the surrounding.

The environmentally friendly floating net cage with a phytoremediation system using aquaponics and artificial wetland plants has been modified and developed so that the water quality in the cages and surroundings is unpolluted or at least releases fewer pollutants by the system. Aquaponic and artificial wetland plants absorb or eliminate organic carbon and nutrients from uneaten feed waste or as phytoremediator agents. The phytoremediation system is potentially applied to an environmentally friendly floating net cage culture system. Uneaten feed as fish farming waste is used as organic fertilizer to grow phytoremediation plants. A study by Rokhmah, Ammatillah and Sastro (2014) stated that in the aquaponic systems, the absorption of nutrients from fish waste is quite adequate, thereby increasing crop production.

Meanwhile, wetland construction effectively reduces pollutants from fish farming activities, such as removing suspended solids, organic matter, ammonia, and nitrite (Endut et al. 2009). Other research had also reported that integrating aquaculture and hydroponics with the addition of nitrifying bacteria improved the water quality of aquaponic (Ajijah et al. 2021). Integrating aquaculture and hydroponics can contribute to crop yield production with less waste and fewer environmental impacts (Krastanova et al. 2022).

This study is a field experiment on removing nutrients in the environmentally friendly floating net cage (FNC), namely a loop bio-phytoremediation system equipped with floating net cages where the uneaten feed and fish excretion would be collected in the bottom of the FNC and treated on the water surface of the lake or reservoir. Loop bio-phytoremediation means that the organic waste and nutrients in the water would be treated biologically by microorganisms and later on fed to the hydroponic and artificial wetland system where the remediation would occur by the presence of the plants as phytoremediators, especially water spinach and vetiver grass. The effectiveness of the organic matter and nutrient removal in the system would be determined.

Materials and Methods

RESEARCH DESIGN

The field experiment on loop bio-phytoremediation of FNC was conducted in the Jatiluhur Reservoir, also called the Ir. H Djuanda Reservoir, Purwakarta Regency, West Java Province, Republic of Indonesia, in August - October 2021 at 6°32’53.61” S latitude and 107°23’21.89” E longitude (Figure 1).

The environmentally friendly floating net cage can be made from conventional FNC by adding some components. Dimensions of FNC are 14 m long, 7 m wide, and 7 m deep. The component of the environmentally friendly floating net cage (Figure 2) are:

1. A floating net cage is equipped with an impermeable layer and a waste container at the bottom of the layer (1). The FNC consists of 3 layers (Figure 3); where the first is the top cover layer (L1) to avoid the release of the feed given, the second layer (L2) is a layer of air and water circulation. The third layer (L3) is an impermeable layer that is made conical (C) and equipped with a container for waste of uneaten feed (CW)
2. Pump (2) to remove waste from the uneaten feed-in container to the water tank as a waste reservoir
3. Two commercial water tanks volume 300 L (3) volumes were used as a reservoir for the extracted wastewater containing uneaten feed. The tank is equipped with a filter made of a fine mosquito net to separate coarse particles and bio balls as bacteria carriers (Pramita, Prasetyanti & Fauziah 2020). Fine mosquito net filter is made like a tube (Figure 2(3)) and attached by hooking it to the top of the tank in a circle. Bioball is light and floating, a growing medium for microorganisms, including nitrifying bacteria, that can remove ammonia contained in water and decompose organic material (Bulan et al. 2023). The uneaten feed and excretion of the fish collected in a container at the bottom of an impermeable layer are pumped and directed to the reservoir tank. The inlet wastewater will be filtered in a fine mosquito net filter, and the waste will be decomposed by bacteria that grow on the bio-ball media. The result of decomposition is water containing fine organic materials, nutrients, nitrogen, and phosphorus

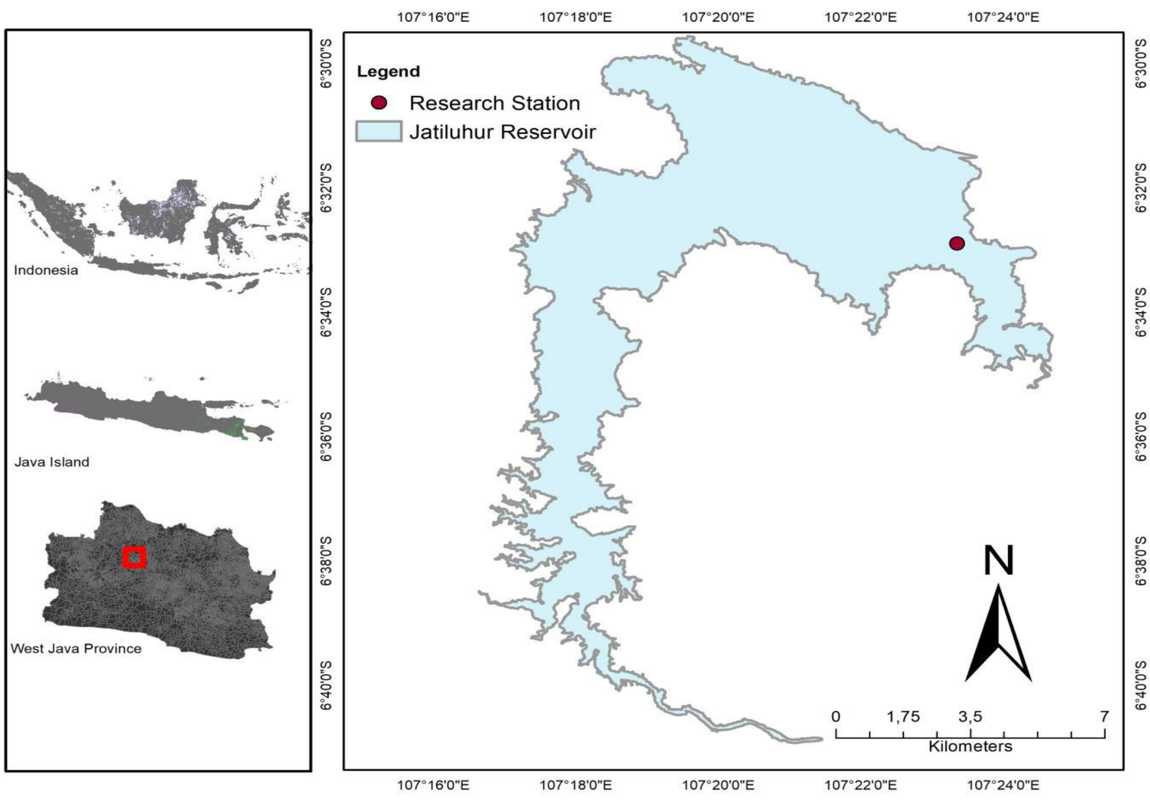


FIGURE 1. The experimental site at Jatiluhur Reservoir, West Java, Indonesia

4. Phytoremediation consists of two types hydroponic water spinach (*Ipomoea aquatic)* (4) and wetland of vetiver grass (*Chrysopongon zizanoides*) (5). Pipes used for hydroponics had a length of 4 m and an inner diameter of 10 cm (0.1 m). The pipe is perforated to place a plastic cup that fills the planting medium. The distance between the holes is 12 cm. Water from reservoir tanks containing organic materials, nitrogen, and phosphorus nutrients is drained into hydroponics with a hydraulic retention time (HRT) of 15 h and then transferred into artificial wetlands with a retention time (HRT) of 36 h. The system will absorb organic materials and other soluble substances available for microorganism use as carbon sources in the hydroponic growing media. The plants will absorb nitrogen and phosphorus as growth nutrients. Hydroponic growing media are charcoal of wood and husks. The combination is good for absorbing waste and pollutants (Azwarudin et al. 2023). The husk of charcoal also has good water-holding properties and potentially be used as a hydroponic medium for water storage. Charcoal is placed into a perforated plastic cup. Water spinach was chosen due to its ability to reduce nitrate, phosphate, and organic matter up to 69.49%, 48.38%, and 42.86%, respectively (Astuti, Warsa & Krismono 2022). Water spinach absorbs nutrients and is used for the speed of growth of plants (Nizam et al. 2020)

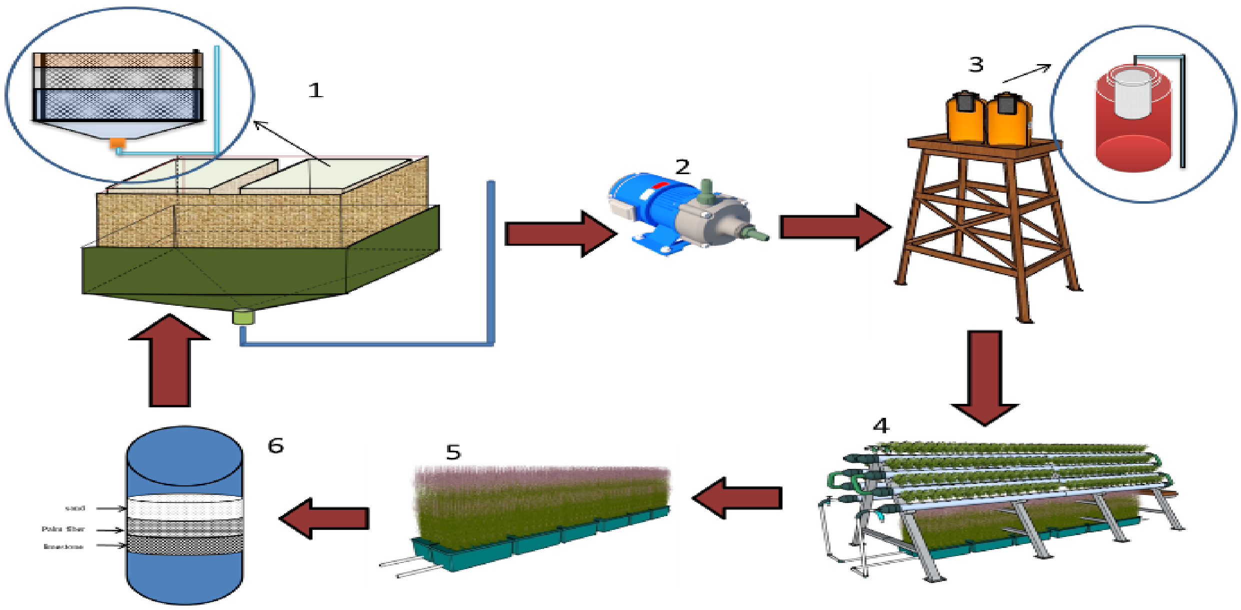


FIGURE 2. Schematic of Ecofriendly floating net cage (FNC) system

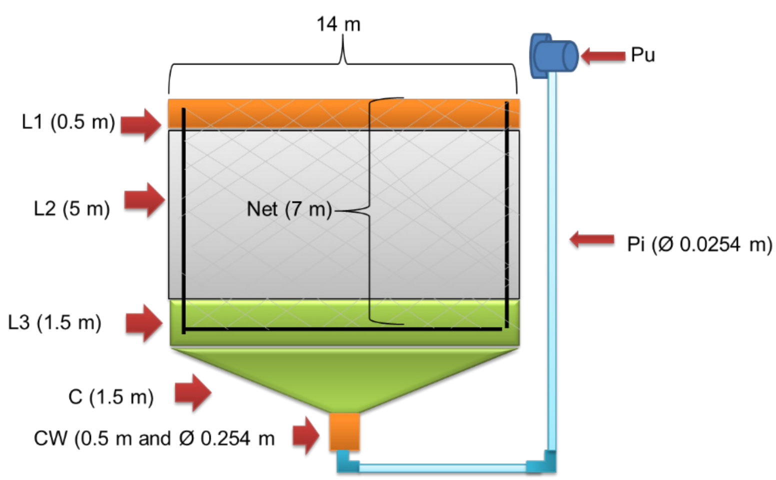


FIGURE 3. The layer of floating net cage consists of (L1) top cover layer, (L2) circulation of water and air layer, (L3) impermeable layer and made conical (C), (CW) container of uneaten feed waste, (Pi) pipeline and (Pu) pump

5. The rest of the organic materials and nutrients in hydroponic would be treated in the artificial wetland using vetiver grass as a phytoremediator, and the artificial wetland media used were sand and limestone. All carbonaceous nutrients, nitrogen, and phosphorous are treated and adsorbed in the system. The artificial wetland's effluent was later filtered in a physical filter unit

6. Physical filter (6) using a tube or bucket with a height of approximately 60 cm and a volume of 30 L. Physical filter consists of three layers, namely sand, palm fiber, and limestone, each with a thickness of 10 cm. Treated water in the hydroponic and artificial wetland units lately channeled into a physical filter with a retention time of 2.4 h (HRT 2.4 h) to eliminate the rest pollution or nutrients. Sand, palm fiber, and limestone would adsorb, reduce impurities, and remove turbidity or mud and odors to maintain water quality (Azwarudin et al. 2023). After the physical filter, treated water would flow directly into FCN waters or reservoirs/lakes.

The mechanism of waste removal in FNC (Figure 2) is by collection of the uneaten feed and fish excretion in a container at the bottom of the FNC (1) connected to a pump (2) by pipeline. The collected waste (1) is later pumped into the reservoir tank (3) through filtration and incubated for a week. Furthermore, after being incubated, the wastewater was transferred to the hydroponic water spinach plant (4) and then to the artificial wetland of the vetiver grass (5). The last remediation process was the filtration of water in a physical filter (6), and in the end, it would be returned to FNC or water body. This recirculation system allows water recycling and fertilization to grow vegetable crops (Oniga et al. 2018).

In the upper nets, it is used for carp (*Cyprinus carpio*) culture with 200 kg or 100 kg per plot and an average of about 15 g per individual seed. While the bottom net for rearing tilapia *(Oreochromis niloticus*) with a total of 200 kg of seeds and an average of about 15 g per individual seed. Feeding is carried out daily (morning, light day, and afternoon) with a satiation system to stimulate the fish's growth and production; the feed is given continuously as long as the fish still receives the feed. If the fish does not respond and moves away from the feed, this indicates that feeding the fish has been completed. This system allows some feed to be wasted in the aquatic system. As a result, feed efficiency will decrease, and the uneaten feed and feces will accumulate in the waters, reducing the water quality (Syamsunarno & Sunarno 2016).

The FNC system used in the experiment was a double-layer. The double-layer FNC system has advantages over the single-layer cage system, in which feed would be utilized by fish kept in the first and second layers of the cages so that the fish of the second layer did not need to be fed. Tilapia can be use as a beneficiary of uneaten feed from the cages above (Nasution, Sari & Huda 2011), so feed is only given to carp in the upper net. The rest of the uneaten feed later on, together with the excretion, would be settled and accumulated in the container at the bottom of FNC. Based on the information on the commercial feed sacks, the feed ingredients used are 28.0% of protein, 6.0% of fat, 5.0% of fiber, 11.0 % of ash, and 11.0% of water.

POINT SAMPLING AND ANALYSIS

A sampling of water was carried out once a week for eight weeks (Figure 4) at the points of (1) water tank as a reservoir of uneaten feed wastewater, (2) effluent of hydroponic (water spinach), (3) effluent of artificial wetland (vetiver grass) and (4) effluent of a physical filter. The samples are preserved in the bottle with sulfuric acid, stored and cooled in a cool box, and transferred for water analysis in the laboratory. The parameters to be determined were total organic matter, nitrate, and phosphorus. The brucine sulfate, ascorbate acid, and permanganate methods were used to determine nitrate, phosphorus, and total organic matter, respectively (APHA 2005*)*.

The following formula calculates the nutrient removal efficiency (RE) (Lekang 2007).

$$RE = \frac{C_{in} - C_{out}}{C_{in}} \, x \, 100\%$$

where RE is the Removal efficiency (%); C_{in} is the initial concentration before treatment (mg/L); and C_{out} is the final concentration after treatment (mg/L). The value (-) indicates an increase in concentration, and (+) indicates a decrease in concentration.

RESULTS AND DISCUSSION

WATER QUALITY

The experiment on the nutrient removal from operated eco-friendly FNC during the cultivation of the fish is shown in Figures 5, 6, and 7. Uneaten feed remains in wastewater of the reservoir tank were incubated for a week and directed by gravitational force to be used as fertilizer for hydroponic plants. The fluctuation of nitrate, organic matter, and phosphorous during the experiment can be seen in Figures 5, 6, and 7, respectively.

FIGURE 4. Point sampling of water quality was carried out once a week; (1) Water Tank as a reservoir of waste, (2) effluent of water spinach hydroponic, (3) effluent of the artificial wetland of vetiver grass, and (4) effluent of a physical filter

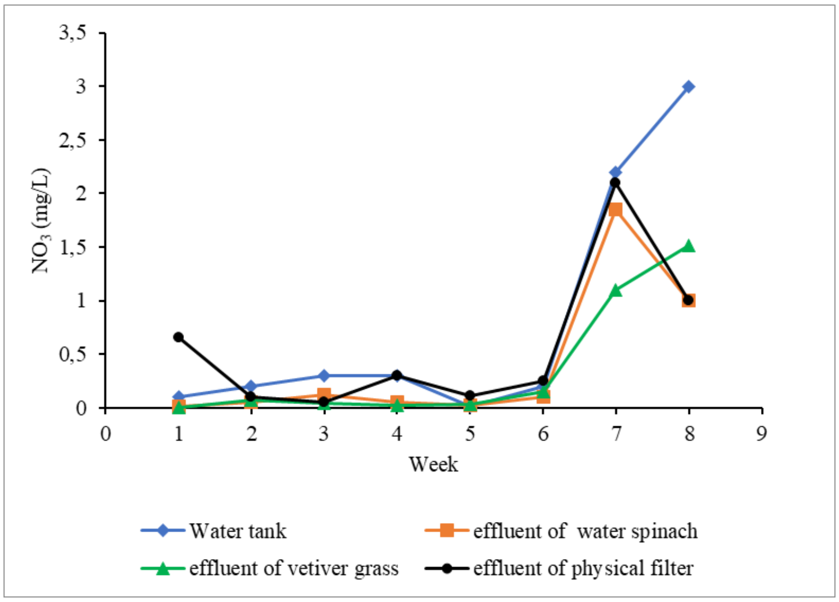


FIGURE 5. The concentration of nitrate (NO_3) during the experiment

Nitrate determination for each point of sampling is shown in Figure 5. The nitrate concentration at the beginning of planting the phytoremediator agent of water spinach and vetiver did not change significantly; however, as the growth of phytoremediator agents increased, the water quality changed. The highest nitrate concentration in the effluent of the reservoir tank reached 3 mg/L, and the lowest was 0.1 mg/L. Nitrates increased with increasing cultivation time. This is presumably because the more feed given, the more uneaten feed was decomposed and nitrified. Only about 29.3% of the feed would be digested, and 52.7% are excreted by urine and 18% by feces (Baveridge 2004). In aquaponics with catfish, the average nitrate concentration in the tank was 0.69 mg/L (Damanik et al. 2018). Nitrogen is an essential element for all living organisms because it is a component of deoxyribonucleic acid (DNA), ribonucleic acid (RNA), amino acids, protein, and other cell components (Oniga et al. 2018). The primary source of nitrogen input in aquaponic systems is uneaten feed and fish excretion in the form of ammonia nitrogen (Timmons et al. 2002).

Bacteria are essential for aquaponics because they can first transform ammonia into nitrite and nitrate (Ajijah et al. 2021; Oniga et al. 2018). The increase in nitrate was observed during the second to the fourth weeks of the experiment and reached the maximum concentration at the end of the experiment. It is shown that organic polymers, especially proteins, are degraded by decomposing bacteria (Figure 6) to form amino acids and ammonia. The increase of nitrate in the liquid media was due to the nitrification process of ammonia by bacteria. Although not all of the nitrate content in the wastewater used and adsorbed in the phytoremediation system, it could be seen that the nitrate was decreased in the outlet of hydroponic, artificial wetland, and physical filter. However, the nitrate content of the water was absorbed by the system and used by the plants either by water spinach and vetiver in the hydroponic and artificial wetland units, and later on absorbed in the physical filter before the processed water entered the FNC and water body.

The total organic matter is increased during the experiment in the reservoir tank. The highest total organic matter in uneaten feed wastewater incubated in a reservoir tank for a week was 386 mg/L (Figure 6) in the sixth week and decreased in the seventh and eighth weeks. The increase of organic matter in the wastewater is indeed in line with the feeding amount of the fish, where the need for feed would increase over time due to the growth of the fish in the FNC; therefore, the amount of total organic matter in the wastewater tank would be increased too. The decrease in organic matter in the seventh and eighth weeks showed that the decomposition process was significant, and the nitrification process also happened (Figure 5). Microbes

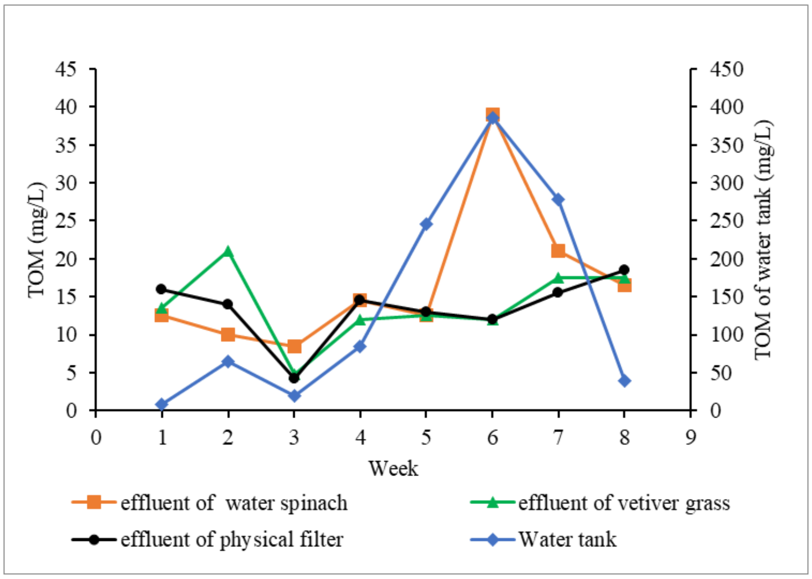


FIGURE 6. The fluctuation of total organic matter (TOM) during the experiment

degrade organic matter from uneaten feed and fish excretion into dissolved nutrients for hydroponic plants. Uneaten feed and solid waste as organic matter must be converted into dissolved inorganic forms that can be assimilated by plants easily (Krastanova 2022). Microbes would also reduce the organic matter in the rhizosphere of water spinach and adsorb the substance to build the plant's structure (Novita, Hermawan & Wahyuningsih 2019). Organic material reduction by the plants could be by phytodegradation, namely absorption and decomposition or mineralization in the plant's cells by a specific enzyme (Asante-Badu et al. 2020).

High phosphorus concentrations were found in water containing incubated uneaten feed waste. Phosphorus is necessary for the development and growth of fish bones. If there is lack of phosphorus, it can cause abnormal development, deformed bones, impaired growth, and even death of fish, as well as if high phosphorus concentrations can disrupt body metabolic processes. Fish use phosphorus according to their body's needs, and unused phosphorus will be excreted in feces and urine (Lestari, Diantari & Efendi 2015). Phosphorus requirements for carp are 0.6 - 0.7% and tilapia 0.8 - 1.0%, while fish feed used in aquaculture activities contains 1.27 - 1.66% (average 1.50%) so that some will be excreted (Ardi 2013). The higher the phosphorus content in the feed, the higher the phosphorus release into the waters. Feeds containing low P of about 1.38%, after 10 min of soaking, will release P into the water about 42 mg/L and *vice versa*; feeds with high P content of about 5.18% and after soaking for 10 min will release P into the water of about 261 mg/L (Sukadi 2010). The phosphorus released into the water is influenced by pH, temperature, oxygen, turbulence, and microbial activity. The feed's nutrient release rate is higher at high temperatures (Kirbia et al. 1997). Based on the results of the study shows that the potential load of phosphorus pollution from the river and tributary (external source) reaches 11,091.5 t/yr and is higher than FNC (internal source) at 2,382 t/yr (Astuti & Tjahjo 2020).

The use of phosphorus by the plants in hydroponic and artificial wetlands can be seen in Figure 7. Phosphorus content in the reservoir tank was adsorbed and used by the plants. Water spinach has used this mineral for growth. In the first week of the experiment, the phosphorus content in the effluent of hydroponic was more than 1 mg/L; later, in the second until the seventh weeks, the amount of phosphorus was less than 0.5 mg/L. However, it increased again in eight weeks. This means that in the beginning, the water spinach needed many nutrients for the growth of the plants, and the use of phosphorus was in line with the use of nitrate and organic matter (Figures 5 and 6). The

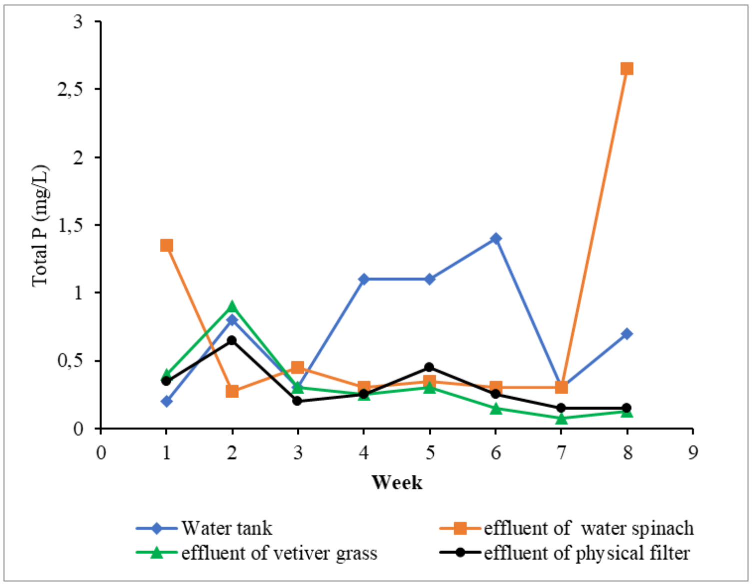


FIGURE 7. The concentration of Total P during the experiment

highest phosphorus (P) concentration was 2.65 mg/L in the effluent of hydroponic; it is also an indication that the decomposition process of organic matter (Figure 6) into minerals was successful.

Meanwhile, the need for water spinach on the phosphorus after eight weeks of growth would be lesser due to the maturity of the plants. However, phosphorus concentration in the effluent of artificial wetlands and physical filters is stable. The phosphorus content in processed water entering the FNC water body at 0.15 mg/L (Figure 7) means the artificial wetland and physical filter are working well.

REMOVAL EFFICIENCY OF NUTRIENTS

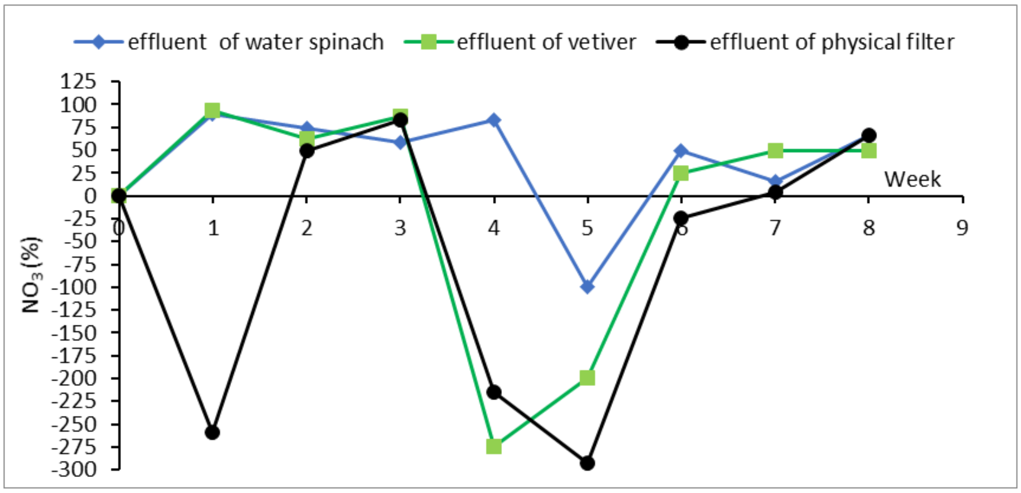
The removal of nutrients by water spinach, vetiver, and physical filters can be seen in Figure 8(a), 8(b), and 8(c). The maximum reduction of nitrate levels from a hydroponic (water spinach), constructed artificial wetland (vetiver grass), and physical filters were 0.25 mg/L (83%), 0.26 mg/L (86%), and 0.25 mg/L (67%), respectively. Meanwhile, the maximum depletion of total organic matter was 233.5 mg/L (94%), 374. 0 mg/L (96%), and 374.0 mg/L (96%), respectively, and the ultimate elimination of total phosphorus from the system was 1.1 mg/L (78%), 1.25 mg/L (89%), and 1.15 mg/L (82%), respectively (Figure 8). The fluctuations in the ability to reduce nutrients by water spinach and vetiver might be related to the increasing decomposition rate in the reservoir tank (Figure 6), and also, the plants still utilize the nutrients which were absorbed the previous week (Utami et al. 2019).

Water spinach hydroponic plants in semi-closed FNC or windowed FNC systems can reduce the content of PO_4, NO_3, and organic matter after passing through aquaponic plants at the rate of 6.3-84.8%; 4.1-77.7%, and 8.8-90.71%, respectively (Astuti, Hendrawan & Krismono 2018). The hydroponically grown water spinach significantly reduced the pollution load of the aquaculture wastewater. The study by Endut et al. (2019) found that the five days of Biological Oxygen Demand (BOD_5), Total Suspended Solid (TSS), Total Ammonium nitrogen (TAN), nitrite (NO_2), nitrate (NO_3), and total phosphorus (TP) reductions were in the range of 2.6-3.6 1 mg/L (47-65%), 49.2-60.3 1 mg/L (67-83%), 6.94-8.44 1 mg/L (64-78%), 0.39-0.51 1 mg/L (68-89%), 8.0-11.6 1 mg/L (42-65%), and 6.8-7.9 1 mg/L (43-53%), respectively. Phosphorus is needed continuously for the root growth of the plants so that phosphorus absorption occurs (Estim, Saufie & Mustafa 2019) in the phytoremediation of waste of FNC.

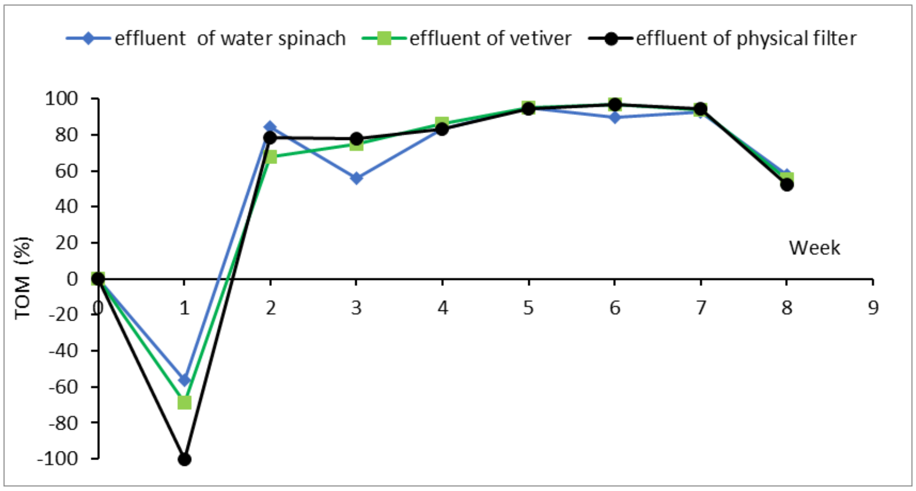
It was reported that lettuce, water spinach, and pak choy potentially absorb nitrate and phosphorus in wastewater. Lettuce, water spinach, and pak choy could absorb nitrate about 0.64 mg/L (12.74%), 1.79 mg/L (26.51%), and 1.85 mg/L (20.98%), respectively (Utami et al. 2015). Pak Choy has the highest capability of the three plants. The PO_4 and NO_3 elimination by spinach was 46.45% and 70.39%. Moreover, PO_4 elimination by mustard greens was 35.98% (Nofdianto & Fauzi 2015).

Vetiver grass is one of the plants that can be used in phytoremediation technology because it can absorb pollutants. The ability of vetiver to absorb nutrients, especially nitrogen (N) and phosphorus (P), has been well-tested (Komarawidjaja & Garno 2016). Vetiver can survive in the media of carwash wastewater and generate new organs and roots (Astuti, Sriwuryandari & Sembiring 2018). Vetiver has a very high capacity for uptaking N and P in polluted water. Vetiver grass is cultivated on a floating platform to treat domestic wastewater. Vetiver could reduce total nitrogen from 9.97-62.48%, while total phosphorus at 6.3-35.87% (Darajeh et al. 2019).

The pollutant substance in 100% carwash wastewater could be removed by vetiver within 70 days, i.e., 9.33 mg/L(57.9%) of total N, 2.23 mg/L(59.3%) nitrate, 0.88 mg/L(69.3%), 8.35 mg/L(69.0%) of total P, 530 mg/L(65.3%) of Chemical Oxygen Demand (COD), 252 mg/L(64.8%) of BOD, 6.12 mg/L(59.5%) of detergent, and 0.11 mg/L(95.8%) of phenol (Astuti, Sriwuryandari & Sembiring 2018). Utilizing vetiver and water spinach as phytoremediation agents is less effective in reducing NO_3 concentrations in the liquid waste of the plywood industry. The highest NO_3 removal efficiency values in control, vetiver, and water spinach were 6.86%, 12.58%, and 19.30%, respectively (Rahmawan, Effendi & Suprihatin 2019). Utilizing vetiver and water spinach as phytoremediation agents effectively absorbs orthophosphate content in plywood industrial wastewater. The elimination of orthophosphate levels in controls, vetiver, and water spinach was 16.89%, 53.90%, and 38.39%, respectively (Rahmawan, Effendi & Suprihatin 2019). It was also reported (Endut et al. 2009) that constructed wetlands effectively removed total suspended solids, 5-day biochemical oxygen demand, total ammonia, and nitrite from the recirculating water under various flow rates.



(a)



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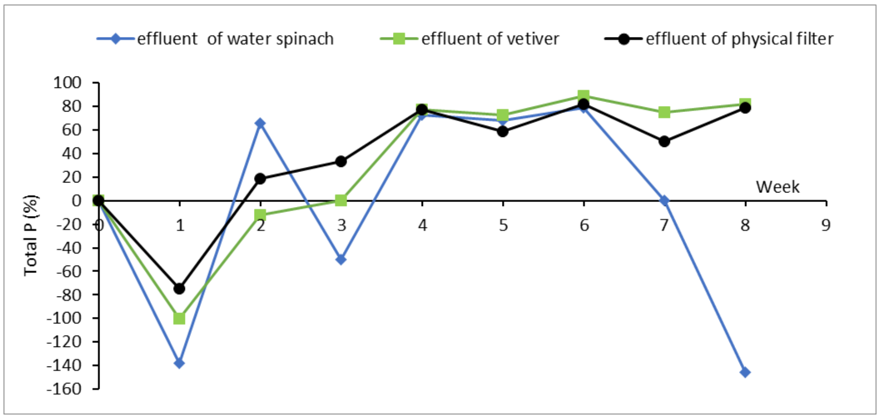

(c)

FIGURE 8. The removal efficiency of nutrients by loop bio-phytoremediation of FNC (a) nitrate (NO_3), (b) Total Organic Matter (TOM), and (c) total P

Conclusions

Loop bio-phytoremediation system equipped with floating net cages is an environmentally friendly floating net cage fish farming technology. It is one solution to reduce the negative impact of N, P pollution, and organic matter from fish farming. This is due to the high effectiveness of the phytoremediation system in reducing nitrate, phosphate, and organic matter. The field experiment showed that the removal efficiency of nutrients on water spinach, vetiver grass, and physical filters in the reducing nutrients benefits the ecosystem and the fish farmer. The maximal reduction in nitrate on water spinach, vetiver grass, and physical filters was 0.25 mg/L (83%), 0.26 mg/L (86%), and 0.25 mg/L (67%), respectively; maximal reduction of the organic matter on water spinach, vetiver grass, and physical filters were reached at 233.5 mg/L (94%), 374.0 mg/L (96%), and 374.0 mg/L (96%), respectively; as well as the highest reduction in total phosphorus on water spinach, vetiver grass, and physical filters were 1.1 mg/L (78%), 1.25 mg/L (89%), and 1.15 mg/L (82%), respectively.

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*Corresponding author; email: lisminingastuti@gmail.com