Aquatic plants as phytoremediator for common carp fish (Cyprinus carpio) culture

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Abstract. This research was conducted to optimize the performance of aquatic plants in maintaining water quality in common carp breeding. This study consisted of three treatments, namely: A. Lemna minor, B. Azolla pinnata, and C. Control (without plant) with three replications. The size of common carp juvenile used was ± 3 cm with a density of 150 individuals/m². Feed was given ad satiation. The parameters observed were survival rate, weight, daily growth rate, water quality such as Biochemical Oxygen Demand (BOD), nitrogen and phosphate reduction. The research design used was Completely Randomized Design (CRD) with Analysis of Variance (ANOVA). Whereas the effectiveness of aquatic plants and water quality analyzed descriptively. The results showed that the highest survival rate and productivity of common carp breeding ponds were in treatment B, namely 86% and 463.80g. The growth rates between the three treatments were not significantly different (p> 0.05), each of which was 0.08; 0.08 and 0.09 g day⁻¹. The BOD reduction results in treatments A, B, and C, respectively 54.65, 54.65 and 52.33%. Nitrogen reduction in each treatment was (A) 67.54%; (B) 87.37%; (C) 25.27%. Furthermore, treatment A and B did not differ in the reduction of elemental P, respectively 52.68 and 55.20%, but in C the reduction was still low at 36.75%. Optimum water quality for dissolved oxygen in treatment A, B, and C respectively 7.24; 7.57 and 3.14 mg L⁻¹. The temperature range between treatments was 24.5 - 27.2 with a pH value of 6.00 - 6.87.

1. Introduction
Intensification or an increase in the density of freshwater fish per unit area of a culture container, has an impact on increasing organic waste from the aquaculture waste itself in the form of fish metabolic waste and food that is not consumed. Pond water sources originating from the river flow are contributors to the pollution of organic waste. Pollution loads of nitrogen (N) and phosphate (P) may accumulate in the aquaculture media and if it occurs continuously may cause some problems and has a negative impact on fish health and freshwater fish production.

One of the activities that utilize the Cikaret river as a source of water for freshwater aquaculture is the Environmental Technology and Toxicology of Freshwater Aquaculture Research and Development. The productivity of fish cultured by this installation continues to decline due to the reduced carrying capacity of the land. This is because of the water quality turn to decrease and resulting in a decrease in dissolved oxygen concentration. Household waste is a type of pollutant that potentially polluting the river. The measurement results proved that total organic matter (TOM) levels...
in the Cikaret river had reached 59 mg L$^{-1}$ higher than the standard limit of 10 mg L$^{-1}$, surfactant 0.1 mg L$^{-1}$ (standard limit 0.02 mg L$^{-1}$), and nitrite 0.09 mg L$^{-1}$ (standard limit of 0.06 mg L$^{-1}$) [1].

The application of phytoremediation techniques was chosen as an effort to decontaminate waste to restore the quality of the polluted environment with natural technologies that are practical, economical, and environmentally friendly. The existence of aquatic plants as a wastewater treatment plant in an aesthetic setting can give a natural and beautiful appearance, even though it functions as a phytoremediation [2]. So that aquatic plants can be used as a phytoremediator. Phytoremediation is part of the concept of natural technology that focuses on the role of aquatic plants as a solution to solving environmental problems. Phytoremediation generally uses aquatic plants for water treatment. Irawanto [3] states that aquatic plants can act as controllers of pollutants. The choice of aquatic plant species is a critical success factor in phytoremediation [4].

According to Lestari [5], aquatic plants in general can absorb certain components so that it is very useful in the waste treatment process. One example of plants used for phytoremediation is *Lemna minor* and *Azolla pinnata*. Research has been carried out to find out about how that aquatic plants could maintain water quality, especially in reducing nitrogen (N) and phosphate (P) nutrients in common carp breeding.

2. Materials and Methods
The research was carried out for 40 days in May-June 2016 at the Research and Development Center for Environmental Technology and Toxicology of Freshwater Aquaculture, Research Institution of Freshwater Aquaculture and Fisheries Extension Bogor. The research was carried out in a stagnant pond without aeration with a size of 5 m x 4 m and 60 cm-depth of water. The study used two aquatic plants for remediation treatments (*L. minor* and *A. pinnata*) and one control (without the addition of aquatic plants). Each treatment was carried out in three replicates. Aquatic plants used for the experiment have a density of about 20-25% of the surface area of the ponds. The fish that used wasa common carp juveniles with a length of 3 cm and a density of 150 fish m$^{-2}$. The feed was given *ad satiation*. The parameters observed were characteristics of *L. minor* and *A. pinnata*, water quality and biological parameters. The water quality parameters observed were temperature, pH that observed in the morning, dissolved oxygen, dissolved nitrogen, dissolved phosphate, and BOD. While the biological parameters measured were fish productivity, growth rate and survival rate. The fish productivity, growth rate, and survival rate calculation were based on the following equation [6]:

- **Absolute Weight** (g) = *Final weight* (g) – *initial weight* (g)  
- **Daily growth Rate**, DGR (%) = \( \frac{\ln (\text{final weight} - \text{initial weight})}{\text{Rearing duration}} \times 100 \)  
- **Survival rate**, SR (%) = \( \frac{\text{Number of fish alive at the beginning of the study (ind)}}{\text{Number of fish alive at the end of the study (ind)}} \times 100 \)

Analysis of variance (ANOVA) and Duncan's test were used to find out which treatments that is significantly different. Meanwhile, the effectiveness of aquatic plants and water quality were analyzed descriptively.

3. Results and Discussion
3.1. Characteristic of aquatic plants
The ability of *Lemna minor* and *Azolla pinnata* to reduce organic waste is based on biomass weight, which is 1.5 kg m$^{-2}$. A number of 1.5 kg m$^{-2}$ is referring to the weight of water plants (1.5 kg) in each pond area (m$^2$). This unit is used to uniform the number of each type of aquatic plant as a treatment in each research pond. So all changes in water quality parameters that occur after the phytoremediation process is the result of the activity of each type of aquatic plant with a biomass weight of 1.5 kg / m$^2$. 
The reduced mechanism takes place by absorption through the roots [7], stems (if it has stem) and plant leaves [8].

The percentage of leaves and roots of *L. minor* and *A. pinnata* plants used as phytoremediation in common carp ponds have different compositions, the composition of *L. minor* plant leaves was more (> 90%) than *A. pinnata* (> 80%) (table 1). The portion of leaf in both types of aquatic plants was dominating. The water concentration of the two plants is > 90%, and is considered very high. *L. minor* and *A. pinnata* plants do not have stems that indicate that the plants are classified as low level plants.

![Figure 1. *L. minor* (a) and *A. pinnata* (b).](image)

Table 1. The composition and moisture content of plants used as phytoremediation.

| Type of Aquatic Plant | Percentage of plant parts (%) | Water Content (%) |
|-----------------------|-------------------------------|-------------------|
|                       | Leaf  | Stem | Root    |                  |
| *L. minor*            | 98.8  | -    | 1.2     | 93.96            |
| *A. pinnata*          | 86.1  | -    | 13.9    | 95.45            |

3.2. Biological test

The highest common carp productivity was obtained in the *A. pinnata* treatment which was 463.80 g and it was not significantly different (P> 0.05) with the *L. minor* treatment (403.53 g), but it was significantly different (P <0.05) with the control (364.63 g). The phytoremediation also has an impact on survival rates of common carp. Based on the calculation of total fish at the end of the study, it was found that the survival rate of common carp for all treatments was > 70% with the highest value obtained in the *A. pinnata* treatment (86%) which was significantly (P <0.05) higher than the control (72%) but not significantly different with the treatment of *L. minor* (81%). This shows that *L. minor* and *A. pinnata* can improve the quality of common carp pond water. Both of these aquatic plants were capable to utilize organic waste resulting from fish metabolism and excess feed for their growth so that the nitrogen and phosphate levels in the water are sufficient to meet the growth demands of common carp. Phytoremediation also increases the level of dissolved oxygen in pond water so that the growth and survival rate of common carp become optimal. According to Sutisna and Sutarmanto [9] good water quality can increase the growth and survival rate of aquaculture species. However, in this study the growth rate of common carp was not significantly different (P> 0.05) between the treatment of *L. minor*, *A. pinnata* and control ponds (table 2).
Table 2. Productivity (g), daily growth rate (g/day) and survival rate (%) of common carp of each treatment at the end of the study.

| Type of Treatments (Aquatic plants) | Average biomass weights (g) Before culture | After culture | Productivity (g)* | Daily Growth Rate (g/day)* |
|-------------------------------------|------------------------------------------|---------------|-------------------|----------------------------|
| L. minor                            | 96.93                                    | 500.47        | 403.53 AB         |                            |
| A. pinnata                          | 97.33                                    | 561.13        | 463.80 B         |                            |
| Control                             | 96.67                                    | 461.30        | 364.63 A         |                            |

| Type of Treatments (Aquatic plants) | Average individual weight (g/ind) Before culture | After culture | Daily Growth Rate (g/day)* |
|-------------------------------------|-----------------------------------------------|---------------|----------------------------|
| L. minor                            | 0.64                                          | 4.14          | 0.08 A                    |
| A. pinnata                          | 0.65                                          | 4.36          | 0.08 A                    |
| Control                             | 0.65                                          | 4.28          | 0.09 A                    |

| Type of Treatments (Aquatic plants) | Average amount of common carp (ind) Before culture | After culture | Survival Rate (%) * |
|-------------------------------------|-----------------------------------------------|---------------|----------------------|
| L. minor                            | 150                                           | 123           | 81AB                 |
| A. pinnata                          | 150                                           | 129           | 86B                  |
| Control                             | 150                                           | 108           | 72A                  |

*) numbers in the same column followed by the same superscript indicate not significantly different (P>0.05)

3.3. Water quality

Sources of water used for research activities in the ponds of Research and Development of Environmental Technology and Toxicology of Freshwater Aquaculture come from the Cikaret river which is becoming a place for household waste disposal along the watershed. Visually the water conditions of the Cikaret river look cloudy, especially when it rains, sometimes foaming, and there is a lot of inorganic waste such as plastic, and rubber. These types of waste are not easily destroyed and are difficult to be degraded in nature.

Water quality parameter is one of the supporting factors which is increasing fish growth and survival rate such as temperature [10]. The temperature ranges obtained on pond water media with L. Minor, A. pinnata or control (without aquatic plants) shows the optimum temperature (table 3) for common carp rearing. The results of temperature and pH measurements for 40 days of common carp rearing showed no difference between the treatment of L. Minor, A. pinnata and control. The temperature range was obtained between 24.5 - 27.9° C. This range is still within the optimum temperature range for common carp growth. According to Khairuman and Amri in Nasir and Khalil [11], the optimum temperature for common carp growth is between 25 - 30°C. The degree of acidity affects the metabolic and physiological processes [12]. The pH value can be used as an indicator for the degradation process of organic matter in a water that can have an impact on fish life. Generally, if there is an excessive degradation of organic matter will be followed by a decrease in pH. This can affect the physiological process of fish, especially in terms of ion exchange. pH values that are too low or too high can cause death. Boyd [13] states that the pH range below 4 is the point of death of fish in acidic conditions, a pH range of 4-5 is the point where the fish cannot produce, the low pH of the water has an impact on the increase in ammonia excretion [14], at pH 5 -6.5 fish growth will slow down, the pH range of 6.5-9 is the suitable range for fish to grow and reproduce, and in the pH range above 11 is the point of death of fish in an alkaline atmosphere. The pH value in water can be influenced by several factors such as photosynthetic activity, temperature, and the presence of anions and cations. The pH value obtained during the phytoremediation process in common carp rearing ranges from 6.0 to 6.87. The measurement was done in the morning. This range still within the
optimum pH range for common carp growth. According to National Standard Agency [15], the pH range for common carp grow this between 6.5 to 8.5.

The dissolved oxygen concentration that measured during common carp rearing showed that the concentration of dissolved oxygen in the source of water (river) was only 3.14 mg L\(^{-1}\), in phytoremediation ponds with \(L. \text{ minor}\) and \(A. \text{ pinnata}\) respectively 7.24 and 7.57 mg L\(^{-1}\) and 6.01 mg L\(^{-1}\) in the control. The high concentration of dissolved oxygen in ponds with the use of aquatic plants shows that the phytoremediation process is going well.

Decomposition of organic substances is a natural phenomena, if a body of water is polluted with organic substances, bacteria will be able to spend oxygen dissolved in water during the biodegradable process (BOD), so that it can cause death in aquatic organisms and the condition of water bodies can be anaerobic which is marked by the onset of bad odor. The higher the level of water pollution, the bacteria's need for oxygen to break down organic matter (BOD) will be even greater. The results of the measurement of BOD value of the source water were 86 mg L\(^{-1}\) and had a significant decrease after the phytoremediation process (table 3), this indicates that the organic substances contained in the water were decreasing. BOD value in \(A. \text{ pinita}\) and \(L. \text{ minor}\) were the same but lower than control. This result showed that \(A. \text{ pinnata}\) and \(L. \text{ Minor}\) were able to reduce BOD. According to Hernayanti and Proklamasiningsih [16], the decrease in BOD is due to the addition of oxygen from the photosynthesis process of aquatic plants (\textit{Pistia stratiotes} L.). In this research the \(L. \text{ Minor}\) and \(A. \text{ pinnata}\) could reduce BOD concentration by 54.65% in 40\(^{th}\) day. While Sutrisno et al [17], states that \(L. \text{ minor}\) can reduce BOD concentrations by 76.54% on the 20\(^{th}\) day of domestic waste in Panggung Lor village, Semarang. Furthermore, the use of \(A. \text{ pinata}\) can reduce BOD in tofu waste by 78.5% in plant density of 3 mg cm\(^{-1}\) which occurred on the sixth day [18]. Although the reduction of BOD value in this study was lower (54.65%) when compared to the value of BOD reduction in Sutrisno et al [17] and Pistal [18], but still considered it good. These two kind of plants could reduce organic waste even though not as good as Sutrisno et al [17] or Pistal [18] research. This was allegedly due to the density of the two aquatic plants in this research was not enough to reduce the waste load contained in common carp ponds.

Reduction in the concentration of nitrogen (N) compounds happened to pond water media, the highest was found in the treatment of \(A. \text{ pinnata}\), followed by \(L. \text{ minor}\). The value of nitrogen concentration after going through the phytoremediation process in \(A. \text{ pinnata}\) plants remained 3.168%, while the nitrogen in \(L. \text{ minor}\) remained 8.145% and 18.75% for control. The high decrease in concentration of N in \(A. \text{ pinnata}\) compared to control and \(L. \text{ minor}\) due to more root components in the plant (13.9%). The root is a part of the plant that functions to absorb water and nutrients such as nitrogen. The more roots the higher the nitrogen that can be absorbed by plants.

Phosphate is needed by all organisms for growth and energy sources. Phosphate concentration value (%) of \(L. \text{ minor}\) and \(A. \text{ pinnata}\) has not different, but significantly different with control, respectively 0.282; 0.267 and 0.377%.

| Table 3. Water quality of common carp ponds after phytoremediation process. |
|----------------------------------|-----------------|-----------------|-----------------|-----------------|
| **Parameter**                    | **Sources**     | **L. \text{ minor}(A)** | **A.\text{pinnata}(B)** | **Control(C)**  |
| Temperature (\(^\circ\)C)        | 24.5            | 27.2             | 27.9             | 25.3            |
| pH                               | 6               | 6.04             | 6.87             | 6.01            |
| Dissolved Oxygen (mg L\(^{-1}\))| 3.14            | 7.24             | 7.57             | 6.01            |
| BOD (mg L\(^{-1}\))             | 86              | 39               | 39               | 41              |
| BOD reduction (%)                | 54.65           | 54.65            | 54.65            | 52.33           |
| Nitrogen(mg L\(^{-1}\))         | 25.09           | 8.145            | 3.168            | 18.75           |
| Nitrogen reduction (%)           | 67.54           | 87.37            | 25.27            |                 |
| Phosphate(mg L\(^{-1}\))        | 0.596           | 0.282            | 0.267            | 0.377           |
| Phosphate reduction (%)          | 52.68           | 55.20            | 36.75            |                 |
4. Conclusion
Phytoremediation techniques have been proven to be able to improve the quality of water pollution of household waste, so that it is suitable to be used for carp breeding. The use of *A. pinnata* and *L. minor* in the phytoremediation process with a weight of 1.5 kg^-1^ m^2^ were better than control (without aquatic plant) because it can significantly increase survival rate and productivity of common carp culture.

5. References
[1] Yosmaniar 2014 Study of water quality for aquaculture in Cibalagung and Cijeruk *Proc. of the Aquaculture Technology Innovation Forum* 379-388
[2] Kusumawardani Y and Irawanto R 2013 Study of plants selection in wastewater garden for domestic wastewater treatment *International Proc of Basic Science Conference* Brawijaya University
[3] Irawanto R 2010 *Jurnal Lokal Wis* 2(4) 29-35
[4] Dick G O, Smart M and Lynde L 2013 Dissolved oxygen concentration *Propagation and Establishment of Native Plants for Vegetative Restoration of Aquatic Ecosystems* (Washington: U.S. Army Corps of Engineers)
[5] Lestari W 2013 The use of *Ipomoea aquatica* for phytoremediation of domestic waste. *Proceeding Seminar of SEMIRATA Faculty of Math and Science Lampung University* 1(1) 441-446
[6] Effendie M I 1997 *Fish Biology* (Yogyakarta (ID): Yayasan Pustaka Nusantara)
[7] Hakim N, Nyakpa Y, Lubis A M, Nugroho S G, Saul M R, Diha M H, Hong G B and Bailey H H 1986 The Basics of Soil Science (Lampung: UNILA Press)
[8] Salisbury F B and Ross C W 1995 *Plant Physiology* 2 translator : Lukman & Sumaryono (Bandung: ITB Press) p 343
[9] Sutisna D H dan Sutarmanto R 1995 *Freshwater Fish Hatchery* (Yogyakarta: Kanisius)
[10] Arjona F J, Chacoff L V, Jarabo I R, Gonçalves O, Páscoa I, Maria P, Río M D and Mancera J M 2009 *Aquaculture* 287 419-426
[11] Nasir M and Khalil M 2016 *Acta Aquatica* 3 (1) 33-39
[12] Abbink W, Garcia A B, Roqtes J A C, Partridge G J, Kloet K, Schneider O 2011 *Aquaculture* 333 pp 130–135
[13] Boyd C E 2015 Water quality. New York (US): *Springer Science* 2(2) 133-136
[14] Golombieski J, Koakoski G, Becker A, Almeida A, Toni C, Finamor I, Pavanato M, Almeida T and Baldisserotto B 2013 *Fish Physiology and Biochemistry Journal* 39 837–849
[15] National Standard Agency 1999 Indonesia National Standard 01-6137-1999: Common carp juvenile production (*Cyprinus carpio Linneaus*) Sinyonya strain juvenile (Indonesia: National Standard Agency) p 1-8
[16] Hernayanti and Proklamasiningsih E 2004 *Jurnal Pembangunan Pedesaan* 4 (3) 164-175
[17] Sutrisno E, Sumiyati S and Nurdiyansyah 2010 *Jurnal Presipitasi* 7 (1) 42-47
[18] Pistal A 2008 Utilization of *Azolla pinnata* to reduce BOD, COD and TSS in tofu liquid waste production continuously *Thesis* (Malang: Department of Environmental Engineering Malang FTSP ITN Malang)