Application of several water plants to reduce organic pollution levels in the Citarum River

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Abstract. The purpose of this research was to determine the most efficient plant to reduce the level of organic pollution in the Citarum River and water quality analysis from the phytoremediation process will be compared with the recommended quality standard of Indonesian Government Regulation No. 82 of 2001 on the Management of Water Quality and Control of Water Pollution. The research was conducted during 7 days at the Aquatic Resources Laboratory of Faculty of Fisheries and Marine Sciences, Universitas Padjadjaran, Sumedang, West Java in June 2019. The method used was an experimental method. The water quality parameters measured include physical parameter i.e temperature, and chemical parameters i.e pH, CO_2, BOD_5, dissolved oxygen, nitrate and phosphate. The results of this research showed *E. crassipes* was able to reduce the concentration of BOD_5 (79.99%), nitrate (12.14%) and phosphate (92.84%). Thus, it concludes the *E. crassipes* is the most effective aquatic plant in reducing the level of organic pollution from Citarum River water samples compared to *P. stratiotes* and *L. minor*.

Key Words: Citarum River, organic pollution, phytoremediation, *E. crassipes, P. stratiotes, L. minor*.

Introduction. One of the rivers in Indonesia, which is in the focus here is the Citarum River. The Citarum River is the longest river in West Java, which extends to 269 kilometers. The upstream of the river is located in Wayang Mountain of South Bandung and the downstream into the north of the island of Java in Bekasi (Nurdjaman et al 2018). The Citarum River is known not only for its size but because of its squalid and polluted condition (Regional Environmental Management Agency West Java 2010).

The results of research from Research Center for Recovery and Conservation of Fish Resources on several water quality data (physical and chemical) in the Citarum watershed indicated that along the Citarum River flow, the waters had been heavily polluted. If this condition continues, it will affect the water quality and ecological function of the river, especially for the source of clean water raw material. Therefore, it is crucial to maintain the sustainability and quality of the Citarum River water resources (Sugianti & Astuti 2018).

Organic pollutants are compounds of chemicals that contain carbon and have a demonstrably negative effect on one or more components of the environment (Ratnakar et al 2016). According to United American Environmental Protection Agency (US EPA 1999), plants can generally be used to degrade organic pollutants by filtering and holding pollutant particles.

Based on the problems that exist in the Citarum River, the technique that is considered to be able to reduce the level of pollution and is more efficient with relatively low cost is using plants or better known as phytoremediation. According to Soetrisnanto et al (2012), phytoremediation is an attempt to use plants to reduce the concentration of waste and environmental pollution problems both ex-situ using artificial ponds or reactors or in-situ (directly in the field) on land or waters contaminated with waste.

Plants that can be used as a phytoremediation agent are aquatic plants, which have the ability to absorb pollutants found in wastewater. Aquatic plants are widely used in phytoremediation because their use is easy and simple and the cost is cheap

(Cahyanto et al 2018). *Eichhornia crassipes*, *Pistia stratiotes* and *Lemna minor* have been studied and many results underlined their effect in phytoremediation through bioaccumulation of pollutants, accumulation of metals and wastewater treatment (Rahmani & Sternberg 1999; Rahman et al 2007; Willey 2007; Dosnon-Olette et al 2011; Ratnani et al 2014; Brăhaița et al 2015; Astuti & Indriatmoko 2018; Cahyanto et al 2018).

The aim of this research was to determine the most efficient plant species to reduce the level of organic pollution in the Citarum River, among the three aquatic plants namely *E. crassipes*, *P. stratiotes* and *L. minor*. In addition, water quality analysis from the phytoremediation process will be compared with the recommended quality standard of Indonesian Government Regulation No. 82 of 2001 on the Management of Water Quality and Control of Water Pollution.

Material and Method

Time and location. The research was conducted during 7 days at the Aquatic Resources Laboratory of Faculty of Fisheries and Marine Sciences, Universitas Padjadjaran, Sumedang, West Java in June 2019.

Research method. The research method used in this research was the experimental method with 3 treatments and 5 repetitions. Plant samples are *E. crassipes*, *P. stratiotes* and *L. minor*. The research preparation phase began by preparing 15 aquaria with a volume of 18 L as a test media container.

Materials (plant samples, standard nitrate, standard phosphate, $MnSO_4$ 50%, O_2 reagent, $Na_2S_2O_3$ 0,01 N, H_2SO_4 5N, $C_{20}H_{14}O_4$ 0,05%, NaOH, $C_6H_6O_7S_2$, NH_4OH 10%, $SnCl_2$, $(NH_4)_6MO_7O_{24}.4H_2O$, H_2O) and tools (aquaria, durant bottles, winkler bottles, analytic scales, dissolved oxygen meter, pH meter, thermometer, UV-Vis spectrophotometer, incubator, burette, microliter pipettes, volumetric pipettes, measuring cylinders, beakers, erlenmeyer flasks, magnetic stirrer, evaporating dishes, water bath, test tubes, funnels, filter papers) were prepared.

The water samples were put as much as 15 L into each aquarium. *E. crassipes*, *P. stratiotes*, and *L. minor* were taken as much as 50 grams each treatment and acclimatized before the research was conducted. The water quality parameters measured include physical parameter i.e temperature, while chemical parameters i.e pH, CO_2, BOD_5, dissolved oxygen (DO), nitrate and phosphate. The temperature, pH, CO_2, dissolved oxygen (DO) were measured every day each treatment during the research, meanwhile BOD_5, nitrate and phosphate were measured each treatment on the first day and the last day of the research.

Determination of the rate of decline in BOD_5, nitrate and phosphate was calculated using the following formula:

$$\mathbf{c} = \frac{\mathbf{Ct} - \mathbf{Co}}{\mathbf{Co}} \mathbf{x100}$$

where: c = decreased rate in BOD_5/nitrate/phosphate (%);
Ct = final concentration;
Co = initial concentration.

Data analysis. Data analysis was done by a descriptor. The data obtained were presented in graphs, then the phytoremediation results compared to each other. In the water quality analysis, the data obtained were compared with the recommended quality standard of Indonesian Government Regulation No. 82 of 2001 on the Management of Water Quality and Control of Water Pollution. Class I, the water that could be used as raw water for drinking water. Class II, the water that could be used for sensitive fish. Class III, the water that could be used for insensitive fish. Class IV, the water could be used to irrigate crops.

One-way Anova was used to determine significant effects of aquatic plant treatments namely *E. crassipes*, *P. stratiotes* and *L. minor* on the absorption rate of

BOD_5, nitrate and phosphate. It was done by using Duncan's honestly significant difference test at $p < 0.05$.

Results and Discussion

Temperature. The results of temperature measurements during research had varied values between treatments. The initial temperature obtained before being given plant treatments was 24.5°C.

The temperature of the three types of plant treatment differed from one another. This was due to differences in leaf cover morphology in the three types of plants. The average temperature in the treatment of *E. crassipes* was 21.46±0.326°C. According to Ratnani (2014), the optimum temperature for the growth of *E. crassipes* ranges between 21 and 30°C. The average temperature of *P. stratiotes* tended to be slightly higher than the other two types of treatment. The average temperature of *P. stratiotes* was 21.62±0.329°C. According to Handoko et al (2016), *P. stratiotes* had a growth tolerance at 15-35°C, while the optimum growth temperature ranged from 22°C-30°C. The average temperature of *L. minor* was 21.40±0.256°C. Kuncoro (2012) stated that *L. minor* could grow well at temperatures of 6-33°C.

The Figure 1 indicates the average temperature for each treatment during the research.

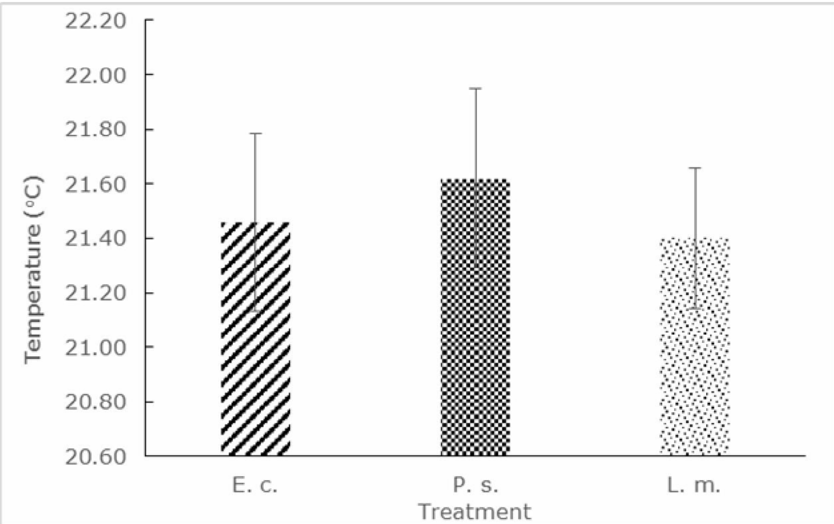

Figure 1. Temperature value during phytoremediation process
(E.c. - *Eichhornia crassipes*, P.s. - *Pistia stratiotes*, L.m. - *Lemna minor*).

Acidity. The initial pH value measured before the phytoremediation process was 6.8. According to Indonesian Government Regulation No. 82 of 2001, pH values for class II and III for fisheries activities ranged from 6 to 9.

The initial pH value measured was still possible for fisheries activities. However, it was less than the maximum of pH value because the Citarum River water contained hazardous materials and had received many pollutant loads (Sugianti & Astuti 2018).

Observation of the pH value was carried out every day as long as 7 days during the phytoremediation process. The pH value of the three types of treatment had increased from the initial pH of measurement. The average pH value of *E. crassipes* during phytoremediation process is 7.56±0.014, the average pH value of *L. minor* during phytoremediation process is 7.36±0.048 and the average pH value of *P. stratiotes* is 7.38±0.007.

The average pH value for each treatment was still in the range of pH values suitable for fisheries activities for class II and III based on Indonesian Government Regulation No. 82 of 2001.

The average pH value for each treatment during the phytoremediation process could be seen in Figure 2.

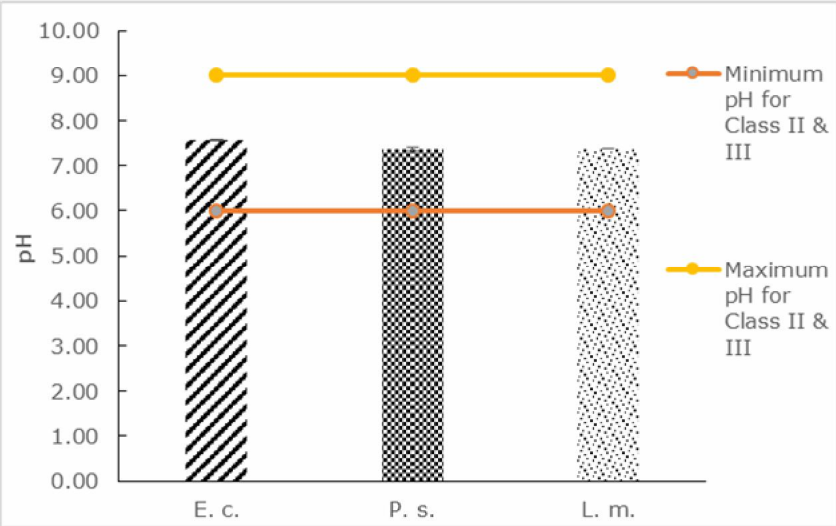

Figure 2. Value of pH during phytoremediation process
(E.c. - *Eichhornia crassipes*, P.s. - *Pistia stratiotes*, L.m. - *Lemna minor*).

Carbon dioxide. The results of measurements of CO_2 concentrations of Citarum River water before phytoremediation was 44 mg L^{-1}. The value of CO_2 concentration before phytoremediation had exceeded the optimum CO_2 value for fisheries activities. The maximum limit of CO_2 concentration for fisheries activities was 15 mg L^{-1} (Astuti et al 2009). The results of CO_2 measurements during the phytoremediation process showed a decrease in each treatment. The best treatment that could reduce CO_2 concentration was *E. crassipes* treatment by 14.71±1.447 mg L^{-1}. Following the treatment of *L. minor* could reduce CO_2 concentration by 17.73±1.209 mg L^{-1} and the treatment of *P. stratiotes* could reduce the CO_2 concentration by 18.73±1.124 mg L^{-1}.

The treatment of *E. crassipes* plant showed that this plant was the most effective of the three types of plants in reducing CO_2 concentrations. The resulting CO_2 concentration values did not exceed the maximum limit of CO_2 concentration for fisheries activities according to Astuti et al (2009). Prasetyawan et al (2017), stated that CO_2 concentration was closely related to pH condition. This was because the higher the pH, the lower the carbon dioxide level.

The results of measurements of average CO_2 concentrations during research could be seen in Figure 3.

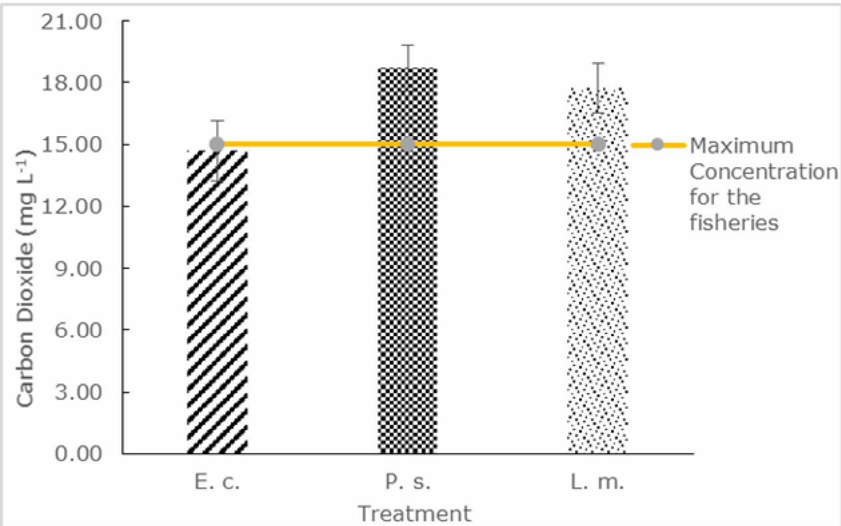

Figure 3. Carbon dioxide concentration during phytoremediation process
(E.c. - *Eichhornia crassipes*, P.s. - *Pistia stratiotes*, L.m. - *Lemna minor*).

Biological oxygen demand. The measurement result of the BOD_5 concentration of Citarum River water before the phytoremediation process was 53.5 mg L^{-1}. This BOD_5 value had exceeded the BOD_5 value standard set by Indonesian Government Regulation No. 82 of 2001 which stated that the BOD_5 value for class II in fisheries activities was 3 mg L^{-1} and class III was 6 mg L^{-1}. According to Silalahi (2010), a BOD_5 value of ≥ 15 mg L^{-1} indicates that the water could be said to have been heavily polluted. This meant that the BOD_5 value of Citarum River water before the phytoremediation process could be said to be heavily polluted.

After the phytoremediation process, the BOD_5 concentration decreased for each treatment (one-way ANOVA [$F_{[2,12]}$ = 42.80, F-table = 3.89]). *E. crassipes* plants showed a relatively faster rate of decline in BOD_5 compared to two other types of plants. *E. crassipes* plants could reduce the BOD_5 concentration by 79.99% (10.70±2.947b mg L^{-1}). The BOD_5 value in the *E. crassipes* treatment indicated that the status of water quality was still slightly polluted which was in the range of 5.1-14.9 mg L^{-1} according to Silalahi (2010).

P. stratiotes plants decreased BOD_5 concentration by 58.17% (22.38±2.405a mg L^{-1}). BOD_5 values in *P. stratiotes* treatment indicated that the status of water quality was still heavily polluted which exceeded at ≥ 15 mg L^{-1} (Silalahi 2010). Whereas *L. minor* plants decreased BOD_5 concentration by 55.74% (23.68±1.850a mg L^{-1}). BOD_5 value in *L. minor* treatment indicated that the status of water quality was still heavily polluted which exceeded at ≥ 15 mg L^{-1} (Silalahi 2010).

The different letters (a, b) indicate significant differences ($p < 0.05$, Duncan's test) between plant treatments. It meant that the rate of BOD_5 reduction in the treatment of *P. stratiotes* and *L. minor* was slightly different from each other, but the two treatments were significantly different from the treatment of *E. crassipes*. The BOD_5 concentration values in all three plant species had exceeded the BOD_5 value standard set by Indonesian Government Regulation No. 82 of 2001 for class II and class III in all three treatments.

The rate of decrease in the average concentration of BOD_5 during research could be seen in Figure 4.

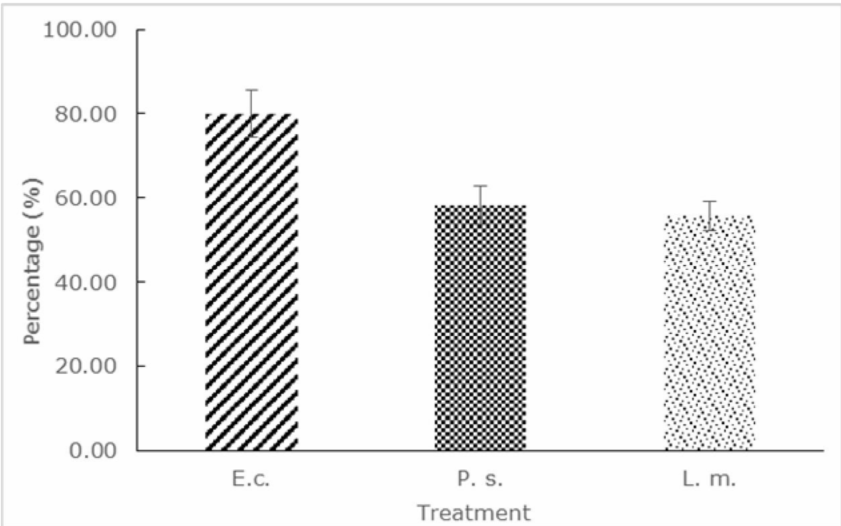

Figure 4. Average decline of BOD_5 concentration during phytoremediation process (E.c. - *Eichhornia crassipes*, P.s. - *Pistia stratiotes*, L.m. - *Lemna minor*).

Dissolved oxygen. The result of the DO measurement before phytoremediation was 3.5 mg L^{-1}. The initial DO value was still possible for fisheries activities. This was in accordance with classes II and III water quality standard according to Indonesian Government Regulation No. 82 of 2001. According to Hardiyanto et al (2012), the concentration of DO values of 0.2 mg L^{-1} in the water could support the activities of the aquatic organisms if there are no toxic compounds in the water.

Based on the average DO value, the *E. crassipes* treatment gave the highest DO value. It was 4.52±0.067 mg L^{-1}, while the average DO value in the *P. stratiotes* treatment was 4.25±0.036 mg L^{-1} and the average DO value in the treatment of *L. minor* was 4.16±0.121 mg L^{-1}. According to Indonesian Government Regulation No. 82 of 2001, the average DO value of the three types of treatment were still in good condition for fisheries activities for class II and class III.

The average DO value during the phytoremediation process could be seen in Figure 5.

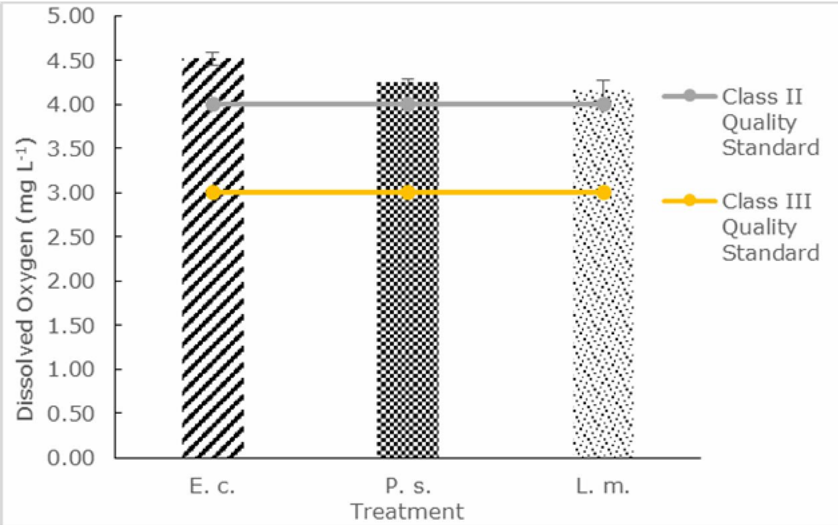

Figure 5. Dissolved oxygen concentration during phytoremediation process (E.c. - *Eichhornia crassipes*, P.s. - *Pistia stratiotes*, L.m. - *Lemna minor*).

Nitrate. The test result of Citarum River water of nitrate concentration before phytoremediation provided the value of 0.229 mg L^{-1}. This result did not exceed the quality standard according to Indonesian Government Regulation No. 82 of 2001 which stated that the concentration of nitrate for class II in fisheries activities was 10 mg L^{-1} and for class III in fisheries activities was 20 mg L^{-1}. Therefore, it could be said that Citarum River water used in the phytoremediation process was still possible to be used in fisheries activities based on nitrate concentration.

The nitrate concentration decreased for each treatment (one-way ANOVA [$F_{[2,12]}$ = 78.38, F-table = 3.89]) after the phytoremediation process. The best treatment that could reduce the nitrate concentration was *E. crassipes* treatment that was equal to 12.14% (0.201±0.0033b mg L^{-1}). *P. stratiotes* treatment was able to reduce nitrate concentration by 3.41% (0.221±0.0035a mg L^{-1}) and the treatment of *L. minor* was able to reduce nitrate concentration by 2.01% (0.224±0.0027a mg L^{-1}).

The different letters indicate significant differences ($p < 0.05$, Duncan's test) between plant treatments. It meant that the rate of reduction of nitrates in the treatments of *P. stratiotes* and *L. minor* were not significantly different from each other, but these two treatments were dramatically different from the treatment of *E. crassipes*.

The average rate of reduction of nitrates for the three types of plants did not exceed the quality standards according to Indonesian Government Regulation No. 82 of 2001 for class II and class III in fisheries activities. Therefore, it could be said that Citarum River water, which had undergone a phytoremediation process was still possible to be used in fisheries activities.

The rate of decrease in the average concentration of nitrate during research could be seen in Figure 6.

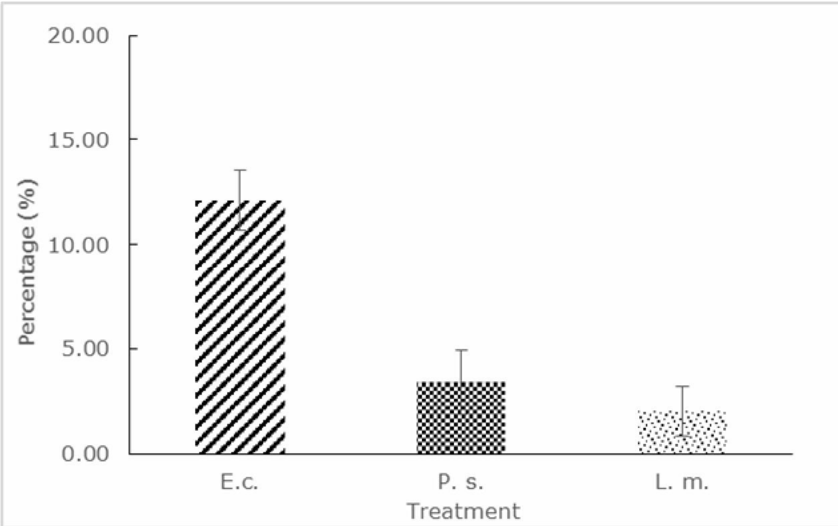

Figure 6. Average decline of nitrate concentration during phytoremediation process (E.c. - *Eichhornia crassipes*, P.s. - *Pistia stratiotes*, L.m. - *Lemna minor*).

***Phosphate**.* The test result of the Citarum River of phosphate concentration before the phytoremediation process was 0.218 mg L^{-1}. This result had exceeded the class II quality standards according to Indonesian Government Regulation No. 82 of 2001 which stated that the concentration of phosphate for class II in fisheries activities was 0.2 mg L^{-1} and class III was 1 mg L^{-1}. Therefore, it could be said that Citarum River water used in the phytoremediation process was still possible to be used in fisheries activities based on phosphate quality standards of class III.

Phosphate concentration test results after phytoremediation process had decreased phosphate concentration for each treatment (one-way ANOVA [$F_{[2,12]}$ = 1926.55, F-table = 3.89]). This meant that all three types of plants work optimally in reducing phosphate concentrations. The best treatment that could reduce the concentration of phosphate was *E. crassipes* treatment that was equal to 92.84% (0.016±0.002b mg L^{-1}). While according to Sudjarwo (2014), *E. crassipes* can reduce phosphate concentrations by 86.14%. *P. stratiotes* treatment could reduce the phosphate concentration by 8.44% (0.200±0.008a mg L^{-1}) and *L. minor* by 5.50% (0.206±0.005a mg L^{-1}).

The different letters indicate significant differences ($p < 0.05$, Duncan's test) between plant treatments. It meant that the rate of phosphate reduction in the treatment of *P. stratiotes* and *L. minor* was not significantly different from each other, but the two treatments were dramatically different from the treatment of *E. crassipes*.

The average yield of phosphate reduction for *E. crassipes* and *P. stratiotes* did not exceed for class II quality standards, but the treatment of *L. minor* had exceeded the quality standard for class II according to Indonesian Government Regulation No. 82 of 2001. While the average rate of decline in the third phosphate treatment of plant species did not exceed the quality standard for class III in fisheries activities.

Therefore, it could be said that Citarum River water, which had undergone a phytoremediation process is still possible to be used in fisheries activities based on phosphate quality standards class III.

The rate of decrease in the average concentration of Phosphate during research could be seen in Figure 7.

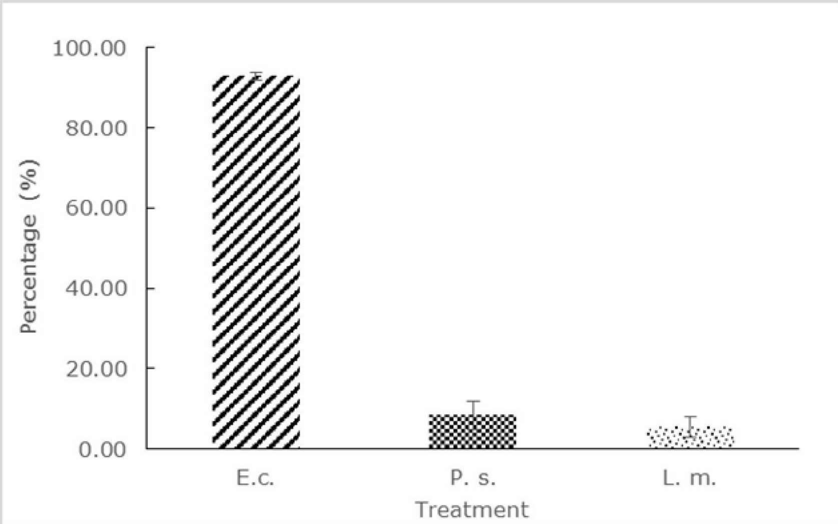

Figure 7. Average decline of phosphate concentration during phytoremediation process (E.c. - *Eichhornia crassipes*, P.s. - *Pistia stratiotes*, L.m. - *Lemna minor*).

Conclusions. The aim of this paper was to determine the ability of plants to reduce the level of organic pollution in the Citarum River. Analysis of physical and chemical parameters showed a significant improvement thereof and it was still in accordance with the recommended quality standard of Indonesian Government Regulation No. 82 of 2001 on the Management of Water Quality and Control of Water Pollution.

The phytoremediation results of this research showed the *E. crassipes* was the most effective plant to improve water quality parameters such as temperature, dissolved oxygen, pH, CO_2, and this plant was able to reduce the concentration of BOD_5, nitrate and phosphate compared to *P. stratiotes* and *L. minor* during phytoremediation process.

Moreover this method is an *in-situ* phytoremediation technology for the polluted waters of organic pollution from the Citarum River. And *E.* crassipes can be used as one solution to the problem of organic pollution in the Citarum River.

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