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Effectiveness of rough horsetail plant (*Equisetum hyemale*) and Mexican sword plant (*Echinodorus paleafolius*) as a phythoremediation agent in reducing cadmium metal (Cd) in the upper Citarum River segment of Dayeuhkolot

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Abstract
Cadmium is one of the pollutants found in the Citarum River which is dangerous because it can accumulate in body tissues and cause toxic effects on organisms. The purpose of this research was to find the water plants that have better absorption ability as phytoremediation agents for heavy metal cadmium between *Equisetum hyemale* and *Echinodorus paleafolius*. This research was conducted at the Ciparanje Greenhouse, Faculty of Fisheries and Marine Science Padjadjaran University from October to December 2020. The parameters observed in this research were water quality (pH, temperature, dissolved oxygen), plant growth, cadmium concentration, and the survival rate of common carp seeds. The results showed that the initial cadmium concentration of 0,0082 mg/L can be reduced with Rough Horsetail to 0,0016 mg/L or 80,08%, Mexican Sword Plant can be reduced to 0,0019 mg/L or 76,42% and the combination between the two aquatic plants can reduce to 0,0005 mg/L or 93,5%.

Keywords: Phytoremediation, aquatic plants, Citarum River, cadmium

1. Introduction
The Citarum River has been used by the people to fulfill the water needs from various aspects such as household, raw water or clean water, irrigation, aquaculture, agriculture, hydropower plants, and local industries [1]. In Bandung Regency, there are approximately 800 textile industries and the waste from the industries is in the form of organic waste, hazardous, and toxic materials such as heavy metal waste which the waste will dump directly into the Citarum River [2]. Heavy metal cadmium waste can come from dyes in the textile industry, alloy industry, metal coating industry, PVC /plastic, battery, and pesticide industries [3]. Heavy metal waste that enters the waters will cause a decrease in the quality of river water. If the pollutants meddle the river for a long time, it will worsen the quality of river water so that water management efforts are needed. Phytoremediation is an alternative to reduce high concentrations of heavy metals in waters by relying on aquatic plants to absorb and accumulate metals to the roots, leaves, or stems [4]. The ability of rough horsetail plant and mexican sword plant to treat heavy metal waste can be used as a phytoremediator. According to Marogawti *et al.* [5], *Equisetum hyemale* has a high silicate content in the stem so it is easy to bind the absorbed particles. According to Caroline and Moa [6] *Echinodorus paleafolius* has a large volume of roots so it is efficient in absorbing metals. Common carp seeds (*Cyprinus carpio*) are used as test animals in wastewater that has gone through the phytoremediation process. Common carp seed is a stage of fish growth that is quite vulnerable, very sensitive to environmental changes and the presence of toxic substances [7]. Common carp have a high enough fat content, so it will be easier to accumulate residues from pollutants to the body tissue [8]. Common carp can be used as a parameter of water biology because they can be maintained on a laboratory scale with an aquarium [9].
The purpose of this study was to obtain a type of aquatic plant that have better absorption of heavy metal cadmium between rough horseetail plant (*Equisetum hyemale*) and mexican word plant (*Echinodorus paleafolius*).

2. Materials and Methods

The research was conducted at the Ciparanje Greenhouse, Padjadjaran University from October to December 2020. Sampling was carried out in the Upper Citarum River in the Dayeuhkolot segment. Analysis of cadmium heavy metal water samples was carried out at the Central Laboratory of UNPAD and the Lembang Balitsa Laboratory and the measurements of temperature, pH, and DO were carried out at Ciparanje Greenhouse, Padjajaran University. The results of the water quality data analysis were compared with the water quality standards according to Government Regulation (Indonesia) Number 82 of 2001 for Class II and III.

2.1 Tools and Materials

The tools used in the study were aquarium, DO meter, pH meter, thermometer, aerator, analytical scale, ruler, Atomic Absorption Spectrophotometer (AAS), camera, jerry can, filter, and measuring cylinder. The materials used in the study were rough horsetail plants, mexican sword plants, goldfish, water sample from the river.

2.2 Research Methods

The research method used is an experimental method. The experiment used was a completely randomized design (CRD) with 4 treatments and 3 replications. The treatments carried out in this study are as follows:

- Treatment A (Control) = Citarum River Water Sample without aquatic plants and given aeration.
- Treatment B = Citarum River Water Sample + 2 clumps of rough horsetail plants (60 stems) and given aeration
- Treatment C = Citarum River Water Sample + 2 talks of mexican sword plants (8 leaf stalks) and given aeration
- Treatment D = Citarum River Water Sample + 1 clump of rough horsetail plants (30 stems)

+ 1 bunch of mexican sword plants (4 leaf stalks) and given aeration

2.3 Research Stages

The initial preparation stage was to acclimatize the rough horsetail plants and the mexican sword plants for 3 days and weigh them according to the treatment. The research stage was to take 5L of water sample for each aquarium. The phytoremediation was caried out for 14 days by measuring the concentration of heavy metal Cd in river water samples, plant weight, and plant length on days 0, 7 and 14. Measurement of pH, DO, and temperature was carried out every day during the phytoremediation process. After the phytoremediation process was complete, an experiment was carried out on test animals, common carp seeds with a size of 3- 5 cm for 7 days then the survival of the seeds was analyzed.

2.4 Analysis Data

The research parameters consisted of physical, chemical and biological parameters, namely DO, temperature, pH, concentration of heavy metal cadmium (Cd), plant growth, and the survival rate for the fish.

The concentration of heavy metal Cd was analyzed using the AAS method or Atomic Adsorption Spectrophotometer. The value of the reduction in heavy metal cadmium (Cd) was analyzed by the formula for the percentage reduction in heavy metal [10]:

$$Redution\ (Ep) = \frac{(A_0 - A_t)}{A_0}\ x\ 100\%$$

Information

A0 = Initial heavy metal concentrations At = Final heavy metal concentrations

The plant growth was analyzed Plant growth by measuring plant weight and length. The change in fresh weight of the plants was calculated using the formula [11]:

Fresh Weight Gain = Final Fresh Weight – Initial Fresh Weight

The percentage of plant growth was calculated using the the formula [12]:

$$\%Wt/day = \frac{Wt - Wo}{Wt \times t} \times 100\%$$

Information

%Wt/day = Plant Growth (%) Wo = Initial wet weight

Wt = Final wet weight

t = Time of the treatments (days)

The survival rate of the common carp seeds was calculated by the formula [13]:

$$SR = \frac{Nt}{No}$$

Information:

SR = Survival Rate (%)

Nt = Number of live fish at the end of treatment No = Number of fish at the beginning of treatment

3. Results and Discussions

3.1 Temperature, pH, and Dissolved Oxygen (DO)

The initial average temperature of the Citarum River in Dayeuhkolot segment before phytoremediation was 28°C. Until the end of the research, the average weekly temperature for 14 days also remained around 28°C (Fig 1). The average temperature value is still in optimal vulnerability for the phytoremediation process. Plants in the phytoremediation process can grow well in a temperature range of 27-30 °C [14].

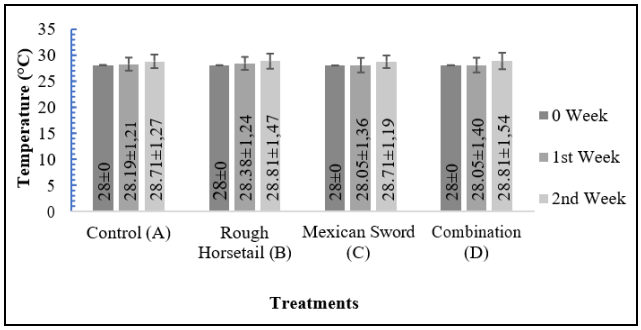

Fig 1: Average Temperature (Weekly)

The initial DO value before the phytoremediation process was 3.5 mg/L, and it is still under the water quality standard PP (Government Regulation) No. 82 of 2001 class, which is namely 4 mg/L. A low DO value will cause a decrease in fish productivity and slower fish growth [15]. After the phytoremediation, the average DO value increased in each treatment (Fig 2). In the second week, the average DO value ranged from 4-5 mg / L and had reached the quality standard of PP. 82 of 2001 class III and class II. The DO concentration value in the plant.

Treatment was relatively higher than the control treatment, this is because the photosynthesis process in plants can produce oxygen which it dissolves in water [16].

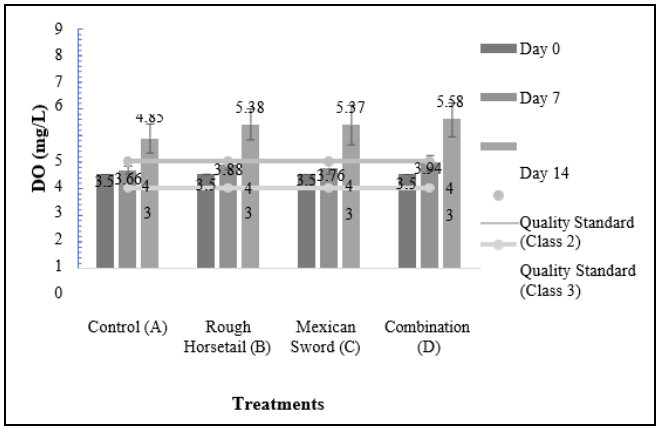

Fig 2: Average Dissolved Oxygen (Weekly)

The initial pH value before phytoremediation was 9, and this value has reached the quality standard tolerance limit according to PP. 82 of 2001, which is 6 - 9 in classes II and III. However, as the phytoremediation process progressed, the average pH value decreased, the average pH value ranged from 8.42-8.62 (Fig 3). The average pH value was still suitable for the growth of the plants. *Equisetum hyemale* has an optimum pH of 6-8, with this pH value the elements in the plant media can be absorb [17] and the optimum pH for *Echinodorus paleafolius* is 4.5-8 [18].

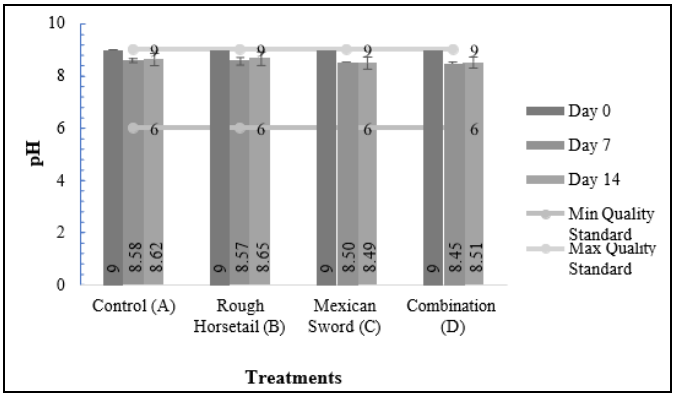

Fig 3: Average pH (Weekly)

3.2 Concentration of Cadmium (Cd)

Measurement of cadmium concentration in water samples before and after treatment shows that both of the plants have the ability to absorb cadmium (Cd). The initial concentration of cadmium was 0.0082 mg/L and after the phytoremediation process, the average cadmium concentration decreased for each treatment. Cadmium concentration does not exceed the quality standard in PP. 82 of 2001, which states that the cadmium concentration for classes II and II in fishery activities is 0.01 mg/L, so it can be said that the Citarum River can still be used for fishery activities. However, this concentration must still be considered because it is close to the quality standard and) cadmium metal is low accumulative and can cause poisoning [19].

The highest decrease in cadmium was found in the combination treatment which is 42.68% or became 0.0047 ± 0.0002 mg / L in the first week and continued to decrease in the second week to 0.0005 mg/L or by 93.50%. Whereas treatment with a rough horsetail plant can reduce the concentration of cadmium in the first week became 0.0057 ± 0.0002 mg/L or by 30.08% and in the second week became 0.0016 ± 0.0002 mg/L or by 80.08. %. Treatment with the Mexican sword in the first week can reduce the concentration of cadmium became 0.0058 ± 0.0003 mg / L or by 28.86% and the second week, the concentration of cadmium became 0.0019 mg/L or 76.42% (Fig 4 and Fig 5). The difference in the decrease in metal concentrations can be caused by differences between the physiology in both of the plants such as thickness and length of roots, leaf width, and the presence of microorganisms in roots or water samples [10].

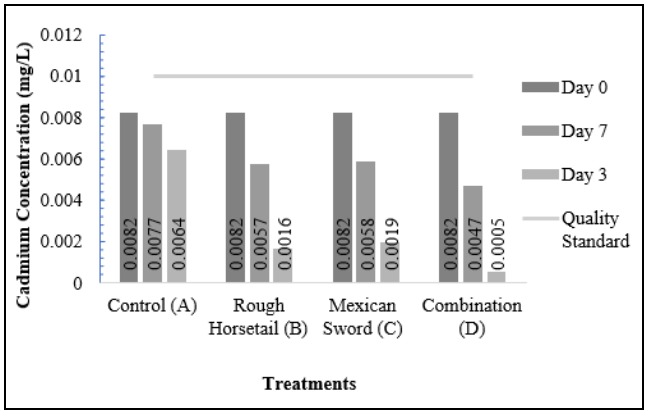

Fig 4: Average Decrease in Cadmium Concentration (Weekly)

Based on the results of analysis of variance (Table 1), there are significant differences in the treatment in reducing cadmium concentrations. It shows that the control treatment is significantly different from the treatment using water plants, and it means that the plants have the ability to reduce the concentration of cadmium. The treatment of rough horsetail plant and mexican sword plant have the same notation value, which it means that mexican sword plant are not significantly different from rough horsetail. But the treatment of rough horsetail plant and mexican sword plant is significantly different from the combination treatment indicated by different notations. Based on this, it can be said that the combination treatment is the most effective in reducing cadmium concentrations. This is could happen because the two plants have their respective advantages.

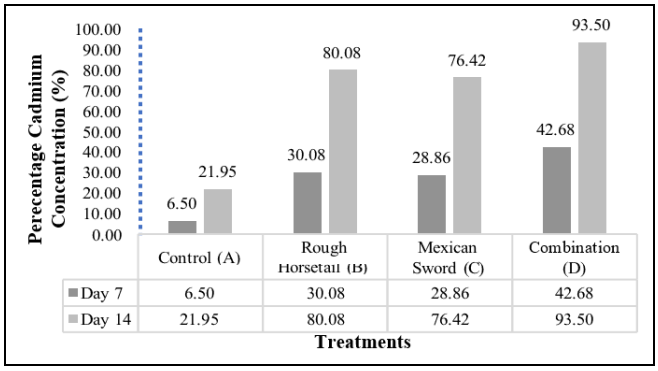

Fig 5: Average Percentage Decrease in Cadmium Concentration

Rough horsetail plant has a high silicate in the stem which functions to bind metal content and accelerate the phytoremediation process [20]. Mexican sword plant has a large, strong, and long root volume so that the place where microorganisms attach to break down pollutants is increasingly widespread [21]. Besides being able to absorb

heavy metals, dissolved oxygen levels can be increased by the use of aquatic plants because during the day water plants carry out photosynthesis which produces oxygen in the process [22].

Table 1: The Average Final Concentration of Cadmium

Treatments	Average
A	21,95a
B	76,42b
C	80,08b
D	93,50c

Note: Different notations indicate a significant difference in Duncan's Multiple Range Test within the 95% confidence level.

3.3 Plant Biomass and Length

3.3.1 Plant Biomass

Plant biomass in rough horsetail treatment increased to 7.61 ± 1.25 grams (0.26%) but in the second week, it decreased by 4.33 ± 0.47 grams (0.08%) from the initial plant biomass. The average biomass of the plant at the end of phytoremediation decreased from 409.67 ± 2.02 grams to 405.33 ± 1.70 grams. Treatment of exican sword had an average initial weight of 277.33 ± 1.25 grams. In the first week, it increased by 3.33 ± 1.25 grams (0.17%) but in the second week, it decreased by 6, 33 ± 1.25 grams (0.17%) from the initial weight so that the average final weight of water jasmine become 271 ± 1.63 grams (Fig 6 and Fig 7).

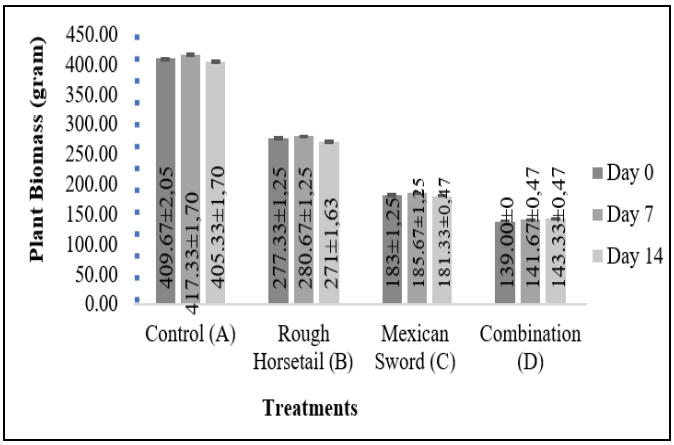

Fig 6: Average Plant Biomass (Weekly)

In the combination treatment, the biomass of the rough horsetail plant and the mexican sword plant were measured separately. The average weight of rough horsetail plant in the first week increased by 3 grams (0.23%) with an initial weight of 182.67 ± 1.25 grams to 185.67 ± 1.25 grams and in the second week, the biomass decreased by 1, 33 ± 0.94 grams (0.05%) from the initial weight to 181.33 ± 0.47 grams. Whereas in mexican sword plants, the average biomass continued to increase for 14 days. In the first week, the weight increased 2.67 ± 0.47 grams (0.27%) and the second week was 4.33 ± 0.47 (0.22%) so that the average biomass of the mexican sword plant was 139 grams to 143,33 ± 0.47 gram at the end of the research.

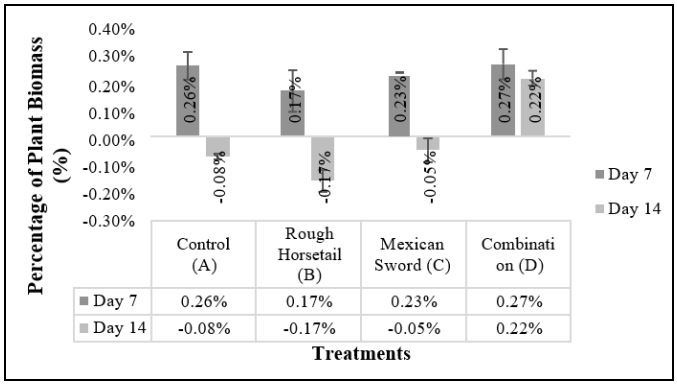

Fig 7: Percentage of Plant Biomass

In the first week, the average biomass of the rough horsetail plant and the mexican sword plant increased compare to the second week. This is presumably because in the first week the nutrients in the growing media were higher than in the second week. According to Kumar [23] the plant growth is thought to be related to the rapid production of photosynthetic pigments in cells and the production of these pigments is influenced by macro and micronutrients in the growing medium.

3.3.2 Plant Length

The average plant length before phytoremediation for both rough horsetail treatment
combination treatment was 70 cm. During the phytoremediation process, plant length increased to 75.33 ± 2.05 cm for rough horsetail treatment and 76.00 ± 2.16 cm for combination treatment. Meanwhile the average plant length for mexican sword treatment and the combination was different. Treatment of mexican sword plant had an average length of 41.33 ± 1.25 cm and a combination treatment of 42.67 ± 2.05 cm. Then during the phytoremediation process, the length of the plants in the water jasmine treatment became 46.00 ± 2.16 cm, while in the combination treatment the length increased to 45.00 ± 2.16 cm (Fig 8).

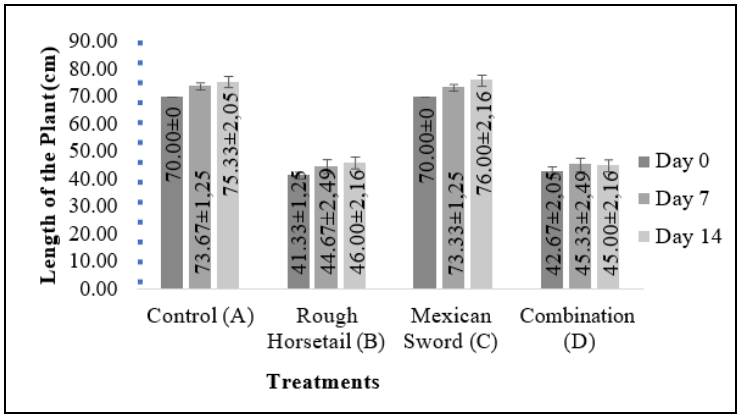

Fig 8: Average Length of the Plant

3.4 Survival Rate

Based on the average survival rate of the common carp seeds (Figure 10), it can be seen that rough horsetail treatment and combination treatment has a 100% of survival rate which means that was no fish die during the maintenance period. In the treatment of mexican sword plant, the survival rate value was 96.67%. Meanwhile, the lowest survival rate value was found in the control treatment without plants, namely 76.67%. The presence of high concentrations of cadmium in waters can be toxic and can cause interference with organ function and death in aquatic organisms [24].

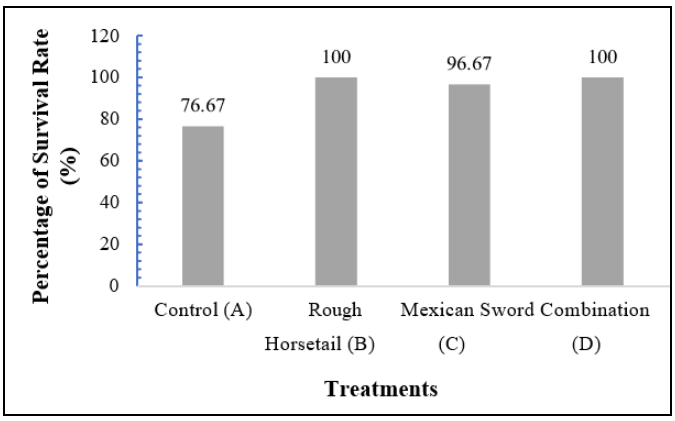

Fig 9: Survival Rate of Common carp

4. Conclusion

Based on the research that has been done, it can be concluded that the combination of rough horsetail plant and mexican sword plant is better to reduce cadmium concentration than other treatments with an initial concentration from 0.0082 mg/L to 0.0005 mg/L or by 93.50%. The combination of rough horsetail plant and mexican sword plant is the most effective treatment and can be recommended as a phytoremediation agent to reduce the level of heavy metal pollution from water samples from the Citarum River as well as a solution to overcome pollution in the Citarum River.

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