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THE EFFECTIVENESS OF WATER SPINACH (*Ipomea aquatica)* IN CONTROLLING THE LEVEL OF SILVER (Ag) IN PHOTOGRAPHIC PROCESSING WASTE LIQUID

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Abstract

One of the most hazardous environmental pollutants that existed is silver liquid waste produced in photographic processing. Some types of water plants are believed to be able to absorb organic, inorganic, and other chemical compounds contained in liquid waste, water spinach (Ipoemea aquatica) being one of them. This study aimed to determine the effectiveness of water spinach (Ipoemea aquatica) in controlling silver liquid waste (Ag) contamination in water. The research design used was randomized block design. The data was then analyzed using a particular formula. The results of the study showed that after 15 days of treatment, water spinach (Ipoemea aquatica) was found to be effective in significantly reducing temperature and level of silver (Ag), but not the pH of the waste liquid. The highest effectiveness was observed when fifteen water spinach (Ipoemea aquatica) plants were used; temperature fell 17.90% (1.60% from the control value; and the level of silver (Ag) fell 5.30%.

Keywords: *silver (Ag), water spinach (Ipoemea aquatica), effectiveness, number of plants.*

INTRODUCTION

With the increasing development activity in various sectors, particularly in the industrial sector, the problem of environmental pollution becomes more and more critical for developed and developing countries. One of the causes of pollution is improper waste disposal from factories that do not have waste treatment units, or if they do have one, it is inadequate to treat the waste. Waste disposal (both solid and liquid) to the waters might lead to contamination, which will make the water unusable.

Heavy metals are toxic materials that can cause damage to aquatic organisms. Heavy metal pollution is mainly caused by mining, metal smelting, and even domestic waste containing heavy metals. An insignificant level of heavy metal (less than 1 μg) is common in natural water. The level of heavy metal pollution in water is divided according to the amount of heavy metal contained; severe, moderate, and non-pollution. Water that is severely polluted by heavy metals usually has a high heavy metal content, as well as the organism living in the water. At a moderate level of pollution, the level of heavy metal contained in water and organisms living in it is within marginal limits. In non-polluted water, the heavy metal content is very low and virtually undetected (Lestari & Trihadiningrum, 2019)

Silver (Ag) is a type of precious metal used in photographic films due to its photosensitive properties. The photographic film development process produces waste containing 1,000-10,000 mg/L (from fixer solution) and 50-200 mg/L of silver (from rinse water). Silver is a hazardous yet precious substance, meaning that it should be completely recovered, both for economic and environmental reasons (Songkroah et al., 2004).

Silver compounds commonly used in photographic processing are silver nitrate ($AgNO3$) and silver bromide (AgBr). The symptoms of silver poisoning include grayish blue discoloration on the eyes, nasal cavity, throat, and skin, skin irritation, ulcers, and digestive disorders caused by overexposure to silver compounds. When entering the body, silver will be accumulated in organs, causing grayish pigmentation called argyria. Pigmentation on the body caused by silver poisoning is permanent, since the body is unable to dispose silver naturally (Said, 2018). Silver nitrate may cause irritation and burning sensation on the skin and mucous membrane, pain in the mouth, diarrhea, vomiting, coma and seizures, and even severe gastroenteritis, which can be fatal. This is proven in research conducted by Sekarwati, which proven that the accumulation of silver in the body continuously will be toxic and lead to several symptoms, including nausea, dizziness and abdominal cramps, damage to internal organs such as liver and kidney, and reproductive disorders (Sekarwati et al., 2015)

Photographic processing is a process to treat a newly exposed film to produce an image. The process is done by soaking celluloid film into three types of solutions; developers, fixers and water. The process must be done in a dark room, since light might damage the image contained in the film. The solutions used in photographic processing contain many chemicals, one of them being silver. Every 1 m^2 of X-ray film that has been used or has been exposed to light contains about 3-3.5 g of silver, while unexposed X-ray films contain 4-6 g/m^2(Khunprasert et al., 2008). According to the Government Regulation of the Republic of Indonesia Number 101 Year 2014 concerning Hazardous and Toxic Waste Management photographic processing waste liquid is included in Category 1, with the maximum level of silver allowed at 0.05 mg/L (Wardhana, 2004). Disposal of untreated photographic processing waste liquid to waters might lead to dangerous consequences. Heavy metals like iron (Fe), Copper (Cu), Nickel (Ni), Argentum (Ag) could cause a number of disorders. Food chain contamination by heavy metals has become a major issue in recent years, since heavy metals may accumulate in the environment through water, soil, and air (Lokeshwari & Chandrappa, 2006).

In order to reduce heavy metal pollution in water, some kind of treatment must be done. One type of treatment that can be considered is using plants that are able to absorb various pollutants (phytoremediation). Plants that are usually used in phytoremediation are floating aquatic plants such as *Scirpus californicus, Zizaniopsis miliaceae, Panicum helito-mom, Pontederia cordata, Sagittaria lancifolia, Ipomea sp,* and *Thypa latifolia,* due to their growth rate and ability to absorb nutrients from wastewater. Their roots become a place of filtration and adsorption of suspended solids and the place for microbes that removes nutrients from wastewater to grow (Juwita et al., 2018). Agricultural plants such as vegetables can easily absorb heavy metals in polluted water. Heavy metals can be absorbed into the plant tissue through its roots and leaves, contaminating food chain. One of the plants capable of absorbing a considerable amount of heavy metal is water spinach (*Ipoemoea aquatica*)(Alloway, 1995).

The concentration of pollutants and exposure time were proven to affect the ability of water spinach (*Ipoemea aquatica*) to absorb Cadmium (a type of heavy metal) and the increase in the biomass of water spinach (*Ipoemea aquatica*). The highest absorption occurred at a concentration of 6 ppm, after 15 days of exposure (5.58 ppm), the highest decline in Cadmium levels occurred at a concentration of 6 ppm, after 15 days of exposure (0.20 ppm), while the highest increase in biomass occurred at a concentration of 2 ppm, after 15 days of exposure (Wulandari, 2014).

The study aims to describe the ability of water spinach (*Ipoemea Aquatica*) in absorbing silver, with different variations of exposure time. The benefit of this study is to provide more information about the ability of water spinach (*Ipoemea aquatica*) to reduce the level of silver contained in photographic processing waste liquid.

MATERIALS AND METHODS

The research design used in this research was randomized block design.

Materials

The research object used in this study was photographic processing waste liquid from developments for color photographs and monochromatic photographs from "X" studio in the city of Bogor. The water spinach plants (*Ipoemea aquatica*) used were taken from Situ Cikaret, Harapan Jaya, Cibinong Bogor on the grounds that those plants have not been polluted with inorganic elements and other heavy metals. The tools used in field experiments were 12 plastic buckets, pH meter, milimeter papers, scales, absorbent paper, thermometer and laboratory equipment.

Research Procedure

The water spinach plants *(Ipoemea aquatica)* used in this research were acclimatized by putting them in plastic tubs filled in mineral water for one week. The plants were then measured and weighed, and plants with similar root lengths and total leaf area were picked. Plants that had been sorted were then moved into other plastic tubs, each containing one liter of photographic processing waste liquid. The design of the experiment is 4x3; meaning that there were four treatments with three replications. The first plastic tub was used as control, and was not planted with water spinach (*Ipoemea aquatica*); the second plastic tub was planted with five clumps of water spinach (*Ipoemea aquatica*); the third plastic tub was planted with ten clumps of water spinach (*Ipoemea aquatica*), and the fourth plastic tub was planted with fifteen clumps of water spinach (*Ipoemea aquatica*). The experiment was conducted for fifteen days.

The parameters measured in this study were the level of silver (Ag), temperature, leaf area, root length and pH of the photographic processing liquid waste, before and after treatment. Analysis of the level of silver (Ag) was carried out using the Atomic Absorption Spectrophotometry (AAS) method with carbon furnace (SNI 6989.63: 2009) with a range of 1 µg/L up to 25 µg/L. The pH was measured using potentiometric method with pH meter, based on SNI 06-6989-11-2004. The temperature was measured using calorimetric method with a thermometer, Lastly, leaf area was measured with gravimetric method, and root length was measured using milimeter papers.

The data was then analyzed using the following formula :

$$e = \frac{\text{Co}-\text{Ci}}{\text{C0}} \text{ x } 100\ \% \qquad (1)$$

Notes: e = effectiveness;
Co = level of silver before treatment
Ci = lever of silver after treatment

RESULT AND DISCUSSION

The data obtained after laboratory analysis on the objects of this study were as follows; level of silver (Ag) contained in the waste: 51.4 mg/L, temperature: 30.8ºC, pH: 5.61, average root length: 21 cm; total leaf area of 5 clumps of plants: 641.7 mm^2, 1044.8 mm^2 for 10 clumps of plants and 1438.6 mm^2 for 15 clumps of plants.

Degree of Acidity (pH)

After 15 days of treatment, there was no significant difference between the pH level of photographic processing waste liquid used as control and the ones that were treated using water spinach plants (*Ipoemea aquatica*), as shown in Table 1.

According to previous research, plants were able to reduce the pH level of water due to the photosynthesis process. The more CO_2 produced in the process, the greater the drop in pH (Haryanti, 2009). In other words, it can be stated that if more plants are used, the effect on pH level will be more significant. Research conducted by Suardana confirmed the statement; his research showed that covering liquid waste from slaughterhouses with aquatic plants helped reduce the pH level of the waste by 24.3% (Suardana, 2009). The same thing was also observed in this study; when five clumps of water spinach *(Ipoemea aquatica)* were used, after 15 days of treatment, the pH level of the waste liquid fell by 0.18%. The figure rose to 0.71% when ten clumps of plants were used, and 1.8% when fifteen clumps of plants were used.

Water containing a high level of metal will have lower pH than usual (acid). A low pH level indicates a high level of heavy metal toxicity (Hutagalung, 1984). The increase in the pH level of waste liquid will reduce the solubility of metal in it. When the pH level of the waste goes up, its stability changes from carbonate into hydroxide, which forms a bond with particles in water, resulting in a muddy substance. Heavy metal toxicity is also influenced by changes in pH levels. The toxicity will increase if the pH level decreases (Sukoasih & Widiyanto, 2017). When the pH level of the waste liquid is close to normal (7-8), the solubility of heavy metals in it is quite stable. The heavy metals in the waste will bind to anions, forming an organometallic complex that tends to settle on the ground (Suwarsito & Sarjanti, 2014). As mentioned earlier, when more clumps are used, the effect will be more significant. Photosynthesis is strongly influenced by the surface area of leaves and roots, since both of them affects transpiration and absorption (Dewi, 2012). This statement was further confirmed by the results of research conducted by Haryanti, which proved that the leaves, leaf stalks and roots of water hyacinth (*E. crassipes)* showed physiological responses against polluted waters. The response also affected transpiration and absorption (Haryanti, 2009) In short, it can be stated that even though the pH of the waste liquid goes down, absorption of silver continues during photosynthesis.

Table 1: The average pH level after treatment using water spinach (*Ipoemea aquatica*) for 15 days

No.	Treatment	Average pH level
1	Control	5.61 a
2	5 clumps	5.60 ab
3	10 clumps	5.57 bc
4	15 clumps	5.52 cd

F_{cnt}(214.2) > F_{tab}(3.24); Least Significance Different$_{(0.05)}$ = 0.31; Least Significance Different$_{(0.01)}$ = 0.04. The mean value followed by the same letter, is not significantly different at the 5% Least Significance Different test level

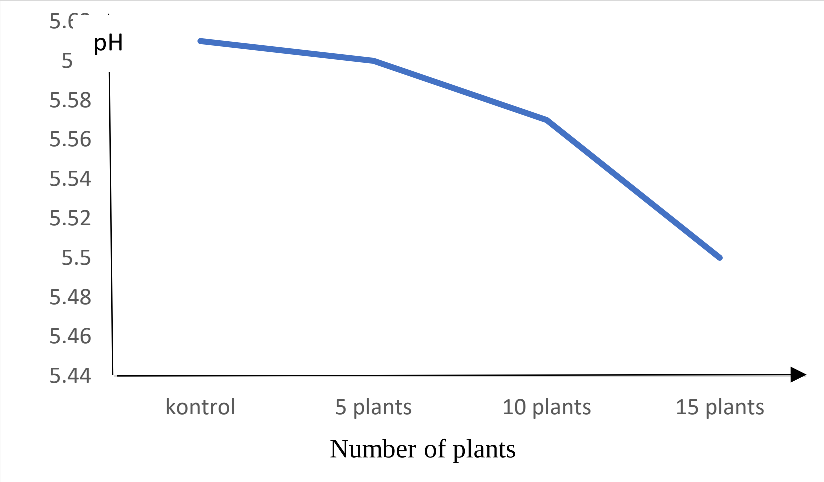

Figure 1: The average pH level after treatment using water spinach (*Ipoemea aquatica*) for 15 days

Temperature

After 15 days of treatment using water spinach (*Ipoemea aquatica*), temperature of the photographic processing waste liquid was significantly different from control. The highest temperature was recorded in the control tub, while the lowest was recorded in the tub treated with fifteen clumps of water spinach (*Ipoemea aquatica*), as shown in Table 2 and Figure 2. The treatment using fifteen clumps of water spinach (*Ipoemea aquatica*) reduced the temperature of the waste liquid by 17.9%. It means that if more plants are used, the effect on temperature will be more significant. The tub treated with fifteen clumps of water spinach was more covered with leaves than the other tubs (which means it has a wider leaf area), which created a larger shade, which helped reduce the temperature further. This confirmed that the factors that influence changes in temperature in the waters are the existence of the shade of trees or plants above it (Chin, 2012).

Table 2: The average temperature after treatment using water spinach (*Ipoemea aquatica*) for 15 days

No.	Treatment	Leaf Area	Average Temperature (ºC)
1	Control	0	30.8 a
2	5 clumps	641.7	27.6 b
3	10 clumps	1044.8	26.4 c
4	15 clumps	1438.6	25.3 d

F_{cnt}(114.3) > F_{tab}(3.24); Least Significance Different$_{(0.05)}$ = 0.83; Least Significance Different$_{(0.01)}$ = 0.24. The mean value followed by the same letter, is not significantly different at the 5% Least Significance Different test level

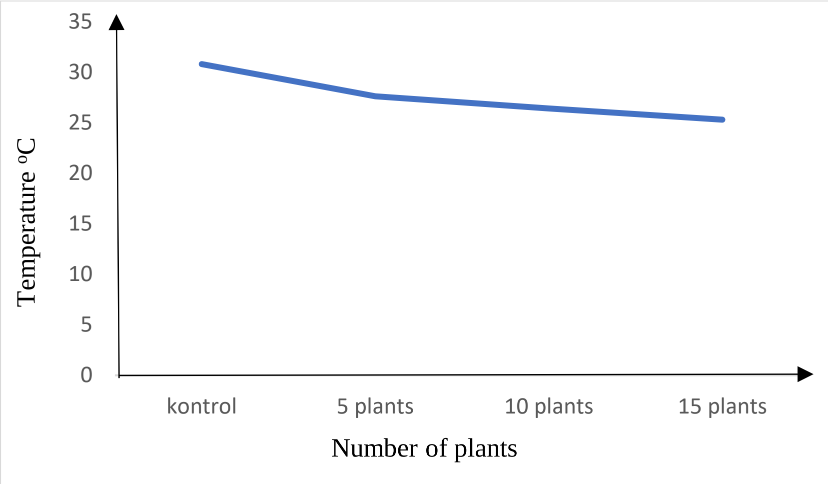

Figure 2: The average temperature after treatment using water spinach (*Ipoemea aquatica*) for 15 days

Level of Silver (Ag)

After 15 days of treatment using water spinach *(Ipoema aquatica)*, there were changes in the level of silver (Ag) contained in the photographic processing waste liquid. The average level of silver (Ag) in the control tub was of 51.4 mg/L. After 15 days of treatment, the average level of silver (Ag) contained in the tub treated with five clumps of water spinach *(Ipoema aquatica)* declined to 49.9 mg/L (a 2.9% decline). The average level of silver (Ag) contained in the tub treated with ten clumps of water spinach *(Ipoema aquatica)* declined to 49.6 mg/L (a 3.5% decline). Lastly, the average level of silver (Ag) contained in the tub treated with fifteen clumps of water spinach *(Ipoema aquatica)* declined to 48.7 mg/L (a 5.3% decline). Table 3 showed that the results of the ANOVA and Least Significance Difference (LSD) tests (significance: 0.05) conducted on the data explained that the difference in level of silver (Ag) after treatment using five clumps and ten clumps of water spinach *(Ipoema aquatica)* was not significant, while the treatment using fifteen clumps of water spinach *(Ipoema aquatica)* showed significant result. This confirmed the results of a study conducted by Djenar and Budiastuti, which shown that when more plants were used, the absorption of substances from polluted water would also be higher (Djenar & Budiastuti, 2008).

By the 15th day, water spinach (*Ipoemea aquatica*) had adapted to the level of silver (Ag) contained in the waste liquid. The decline in the level of silver (Ag) was also shown in Figure 3. This confirmed the results of a study from Wulandari, which stated that after 15 days of exposure, the adaptation process of water spinach *(Ipoemea aquatica)* would be more optimal, so that the growth rate will be more stable (Wulandari, 2014) Another study on the potential of water spinach *(Ipoemea aquatica)* as a phytoremediation plant showed that it was able to absorb detergent waste, reducing the level of detergent by 54.17% in 28 days. The highest absorption occurred on day 7 and 14 (al Idrus et al., 2021).

Table 3: The average level of silver (Ag) after treatment using water spinach *(Ipoemea aquatica)* for 15 days

No.	Treatment	Average of the difference in level of silver (Ag) (mg/L)	Average level of silver (Ag) (mg/L)
1	Control	51.4	51.4 a
2	5 clumps	1.5	49.9 ab
3	10 clumps	1.8	49.6 bc
4	15 clumps	2.7	48.7 c

F_{cnt}(114.2) > F_{tab}(3.24); Least Significance Different$_{(0.05)}$ = 0.41; Least Significance Different$_{(0.01)}$ = 0.09. The mean value followed by the same letter, is not significantly different at the 5% Least Significance Different test level

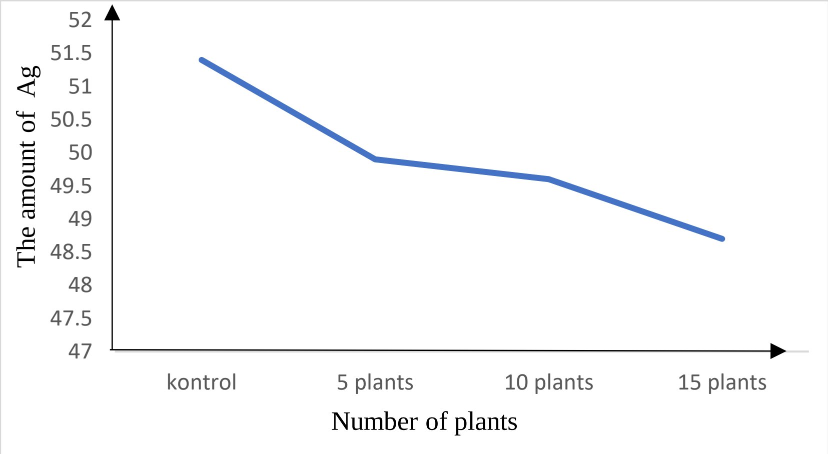

Figure 3: The average level of silver (Ag) after treatment using water spinach *(Ipoemea aquatica)* for 15 days

The absorption of silver (Ag) affects the physiology and morphology of water spinach *(Ipoemea aquatica)*, including their biomass. The plants are forced to adapt to silver (Ag) to survive. The need for nutrients forced the plants to absorb heavy metals along with nutrients. The plants will then neutralize the toxic substances and release them as a form of adaptation to silver (Ag).

Absorption and accumulation of heavy metals in plants can be done through their roots (Priyanto & Prayitno, 2007). The root is an organ of water spinach plants serving to absorb water, nutrients, and organic material in its medium. The absorption of silver (Ag) by the roots of water spinach *(Ipoemea aquatica)* lead to a decline in the level of silver (Ag) contained in the photographic processing waste liquid. Root length and total leaf area also affect the absorption of substance by water spinach *(Ipoemea aquatica)*. It means that if more plants are used, the absorption of substance (in this case silver) will be higher. After 15 days of treatment, the average length of roots of the water spinach *(Ipoemea aquatica)* used in the tub treated with five clumps of plants rose to 23.6 cm. The average length of roots of the water spinach *(Ipoemea aquatica)* used in the tub treated with ten clumps of plants increased to 23.8 cm. Finally, the average length of roots of the water spinach *(Ipoemea aquatica)* used in the tub treated with fifteen clumps of plants rose to 24.1 cm. Water spinach *(Ipoemea aquatica)* can function as a biofilter due to its ability to break down organic and inorganic objects around its roots. Inside the stem and roots of water water spinach *(Ipoemea aquatica)* there is a type of tissue called parenchyma, which brings oxygen to the roots (Juwita et al., 2018).

CONCLUSION

Based on the results of the study, it can be concluded that after 15 days of treatment using water spinach *(Ipoemea aquatica),* the temperatire of photographic processing waste liquid and the level of silver (Ag) contained in it dropped significantly, but the treatment had no real effect on the liquid waste's pH level. The highest effectiveness was observed when fifteen clumps of water spinach *(Ipoemea aquatica)* were used. Water spinach *(Ipoemea aquatica)* can be used for waste control, however due to its rapid growth rate, it might lead to siltation of waters, so the plants need to be controlled. A suggestion for topic of future research is to analyze the spread of silver (Ag) in parts of water spinach *(Ipoemea aquatica)* using radioisotope technique.

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