

COMPARISON OF THE EFFECTIVENESS OF WATER LETTUCE (*PISTIA STRATIOTES*) AND WATER HYACINTH (*EICHHORNIA CRASSIPES*) IN REDUCING AMMONIA FROM TOFU WASTEWATER THROUGH PHYTOREMEDIATION

Ilham Fuadi, Arifin, Sulaiman Hamzani, Tien Zubaidah

Environmental Health Department, Poltekkes of the Ministry of Health Banjarmasin

Jl. H. Mistar Cokrokusumo No.1A Banjarbaru, South Borneo, 70714

E-mail: ilhamfuadi25@gmail.com

Article Info

Article history:

Received July 30, 2023

Revised August 01, 2023

Accepted January 27, 2025

Keywords:

Tofu wastewater

Ammonia

Water lettuce

Water hyacinth

Phytoremediation

ABSTRACT

Comparison Of The Effectiveness Of Water Lettuce (*Pistia Stratiotes*) And Water Hyacinth (*Eichhornia Crassipes*) In Reducing Ammonia From Tofu Wastewater Through Phytoremediation. Tofu industries produce wastewater containing ammonia, which has the potential to pollute the environment. One method of treating such wastewater is phytoremediation, which involves the use of aquatic plants to absorb or reduce pollutant concentrations. This study compares the effectiveness of two types of aquatic plants, namely water lettuce (*Pistia stratiotes*) and water hyacinth (*Eichhornia crassipes*), in reducing ammonia levels in tofu wastewater. This research employed a quasi-experimental design with a pre-test and post-test approach using two comparative treatments. The samples consisted of 12 treatment units with water lettuce, 12 units with water hyacinth, and 4 control units without treatment. Data analysis was conducted using the Wilcoxon test. The results showed that the control group experienced a 27.3% reduction in ammonia levels. The water lettuce groups with weights of 300, 600, and 900 grams showed reductions of 80.3%, 82.7%, and 74.1%, respectively. Meanwhile, the water hyacinth groups demonstrated reductions of 74.5%, 77.7%, and 86.4%, respectively. Statistical analysis yielded a p-value of 0.001 ($p < 0.05$), indicating a significant difference between pre- and post-treatment conditions. In conclusion, both water lettuce and water hyacinth were effective in reducing ammonia levels in tofu wastewater, with the highest effectiveness achieved by water hyacinth at a weight of 900 grams.

This is an open access article under the [CC BY-SA](https://creativecommons.org/licenses/by-sa/4.0/) license.



INTRODUCTION

Tofu industries are among the most commonly found enterprises in Indonesia. As the number of tofu industries increases, so does the volume of wastewater they generate.^[1] Most tofu industries still use simple technologies with low resource efficiency, resulting in the production of large amounts of waste, particularly liquid waste.^[2] This wastewater cannot be directly discharged into the environment due to pollutant concentrations that exceed the quality standards set by the government, such as those stipulated in the South Kalimantan Governor Regulation.^[5] One of the main pollutants in tofu wastewater is ammonia.^[6]

The ammonia content in wastewater can have toxic effects on aquatic organisms, especially when dissolved oxygen levels are low and the pH and temperature are unstable.^[7] Therefore,

tofu wastewater must be treated before being released into the environment. One environmentally friendly treatment method is phytoremediation, which involves the use of plants to absorb or neutralize pollutants in wastewater.^[89] This method has been widely applied for the remediation of contaminated water and soil in various regions.^[10]

This study utilizes two types of fast-growing aquatic weeds, namely water lettuce (*Pistia stratiotes*) and water hyacinth (*Eichhornia crassipes*).^{[11][2]} Prior to the phytoremediation process, both plants underwent an acclimatization phase, which is a gradual adjustment to the wastewater environment.^[13] Previous research has shown that water lettuce can reduce BOD by 92.70%, COD by 96.05%, and TSS by 84.64%.^[14] Meanwhile, water hyacinth has been reported to reduce BOD by up to 97.31%, TSS by 94.76%, and COD by 72.91%.^{[15][6]} Another study also demonstrated that both plants, with a biomass of 300 grams and a contact time of 28 days, could reduce organic matter by up to 75%—with reductions of around 70% achieved as early as the 7th day.^[17] However, that study used tofu wastewater that had been diluted with clean water at a 1:3 ratio.

This study aims to assess the effectiveness of water lettuce and water hyacinth in reducing pollutant levels in undiluted tofu wastewater, using different parameters, contact times, and pollutant concentrations than those employed in previous studies.

MATERIALS AND RESEARCH METHODS

The equipment used in this study included a set of tools for measuring ammonia levels, pH, and temperature, as well as tools for conducting the phytoremediation process. The materials used consisted of water lettuce (*Pistia stratiotes*), water hyacinth (*Eichhornia crassipes*), tofu industry wastewater, well water, standard ammonia solution, distilled water, potassium hydrogen tartrate ($C_4H_4O_6 \cdot 4H_2O$), mercury iodide (HgI_2), potassium iodide (KI), sodium hydroxide (NaOH), and research data tabulation forms.

The method began with the collection of water lettuce and water hyacinth from Marapura Lama. The plants were then transported to the research site located at a private residence on Kasturi 1 Street, Astoria Alley. Prior to the phytoremediation process, an acclimatization phase was conducted to allow the plants to gradually adapt to the tofu wastewater environment.

The acclimatization process lasted for six days. On the first day, the water lettuce and water hyacinth were submerged in 3 liters of well water. Over the next five days, tofu wastewater was incrementally added to the water at a rate of 10% per day until the sixth day, when a full acclimatization level was reached. At the end of this period, plant viability was assessed. Plants that died during acclimatization were excluded from the phytoremediation phase, while only those that survived were used in the next stage.

During the phytoremediation process, regular observations were conducted, including measurements of wastewater pH, water temperature, and ambient air temperature. On the 10th day of the study, samples were collected for further analysis.

RESEARCH RESULTS AND DISCUSSION

Table 1 presents the comparative efficiency of water hyacinth and water lettuce in reducing ammonia concentrations through a 10-day phytoremediation process:

Table 1. Efficiency of Water Hyacinth and Water Lettuce in Reducing Ammonia via 10-Day Phytoremediation

Weight Variation	Plant Type Variation					
	Water Lettuce (<i>Pistia stratiotes</i>)			Water Hyacinth (<i>Eichhornia crassipes</i>)		
	Before Treatment (mg/l)	After Treatment (mg/l)	Amount of Reduction (mg/l)	Before Treatment (mg/l)	Before Treatment (mg/l)	Amount of Reduction (mg/l)
0 Gram	0,66	0,48	0,18	0,66	0,48	0,18
300 Gram	1,42	0,28	1,14	2	0,51	1,49

600 Gram	2,26	0,39	1,87	1,97	0,44	1,53
900 Gram	1,7	0,44	1,26	2,25	0,30	1,95

In the control group (0 grams), a reduction in ammonia concentration was observed from 0.66 mg/L to 0.48 mg/L, indicating a decrease of 0.18 mg/L or approximately 27.3%. This reduction was attributed to the high ambient temperature during the experiment, where the research site experienced a heatwave, reaching temperatures up to 35°C. This temperature exceeds the boiling point of ammonia, which is 33.3°C. Since ammonia is highly soluble in water, its solubility is influenced by temperature; at higher temperatures, ammonia concentrations tend to decrease.^[18]

Pistia stratiotes (water lettuce) at a weight of 300 grams was able to reduce ammonia levels by 1.14 mg/L, from an initial concentration of 1.42 mg/L to 0.28 mg/L, representing a reduction efficiency of approximately 80.3%. At 600 grams, the reduction was 1.87 mg/L, from 2.26 mg/L to 0.39 mg/L, or around 82.7%. At 900 grams, the reduction reached 1.26 mg/L, from 1.76 mg/L to 0.44 mg/L, or approximately 74.1%.

The weight variations of 300 and 600 grams demonstrated ammonia reduction efficiencies of 80.3% and 82.7%, respectively. This is likely due to *Pistia stratiotes* having fibrous roots, which provide surfaces for suspended colloids to adhere to in water, as well as its ability to produce oxygen through photosynthesis. This oxygen is utilized by microorganisms to break down organic substances in the wastewater.^[19] The organic matter present in the wastewater is decomposed by microorganisms into simpler compounds that can then be absorbed by the plants as nutrients.^[20] Furthermore, *Pistia stratiotes* can absorb dissolved nutrients through its roots.^[21] Since ammonia consists of nitrogen and hydrogen, both of which are essential nutrients, *Pistia stratiotes* can absorb these elements, thereby reducing the ammonia concentration in the water.

However, at 900 grams, the reduction efficiency declined to 74.1%. This lower efficiency, or relative increase in ammonia levels, was attributed to the decay and death of some *Pistia stratiotes* plants. The presence of decaying plant matter in the wastewater can lead to an increase in ammonia levels through a process known as ammonification.^[22]

Table 2. Reduction of Ammonia Concentration by Water Hyacinth (*Eichhornia crassipes*)

Plant Weight (gram)	Initial Ammonia Concentration (mg/L)	Final Ammonia Concentration (mg/L)	Reduction (mg/L)	Percentage Reduction (%)
300	2.00	0.51	1.49	74.5%
600	1.97	0.44	1.53	77.7%
900	2.25	0.30	1.95	86.5%

Research findings revealed that water hyacinth (*Eichhornia crassipes*) was capable of significantly reducing ammonia concentrations in tofu wastewater, and its effectiveness increased in line with the increasing plant biomass used. At a weight of 300 grams, the ammonia concentration decreased by 1.49 mg/L, from 2.00 mg/L to 0.51 mg/L, equivalent to a reduction of 74.5%. At 600 grams, the ammonia level decreased by 1.53 mg/L, from 1.97 mg/L to 0.44 mg/L, corresponding to a 77.7% reduction. Meanwhile, at 900 grams, the highest reduction was observed, namely 1.95 mg/L, from 2.25 mg/L to 0.30 mg/L, with a percentage decrease of 86.5%.

These data indicate that the greater the biomass of water hyacinth used, the higher the plant's ability to absorb ammonia from the wastewater. This finding demonstrates the phytoremediation potential of *Eichhornia crassipes* as an effective biological solution for reducing ammonia pollutants in tofu wastewater.

At biomass variations of 300, 600, and 900 grams, a reduction in ammonia concentration was observed with efficiencies of 74.5%, 77.7%, and 86.5%, respectively. This is attributed to the ability of water hyacinth to improve ammonia content in tofu industrial wastewater, in addition to its fibrous root system with numerous root hairs. This type of root structure accelerates the decontamination process. This finding aligns with the study by,^[23] which

states that the effectiveness level of a plant in absorbing pollutants can be identified by the fibrous roots it possesses. Aquatic plants that float on the water surface generally have dense fibrous roots. These roots contain many root hairs of approximately equal size, emerging from the root base and spreading sideways in all directions. Fibrous roots form branches of relatively uniform size.

The contaminant decontamination process occurs via phytovolatilization, a process that involves the use of plants to uptake contaminants from groundwater, transform them into volatile forms, and transfer them to the atmosphere.^[24] Phytovolatilization involves contaminants that are absorbed into the plant body, where volatile contaminants or their volatile degradation products are transported with water vapor through the leaves.^[25]

The statistical test used was the paired samples t-test; however, prior to its application, a normality test was conducted. Since one of the values was not normally distributed ($p = 0.001 < 0.05$), the paired samples t-test could not be used, and the analysis proceeded with the Wilcoxon test. Following the Wilcoxon test, a p-value of $0.001 < 0.05$ was obtained, indicating a significant difference between pre- and post-phytoremediation conditions. Therefore, the conclusion is that H_0 is accepted—there is a significant difference before and after the phytoremediation process using *Pistia stratiotes* and *Eichhornia crassipes* in reducing ammonia levels in tofu wastewater.

CONCLUSIONS AND RECOMMENDATIONS

Based on the research results, both *Pistia stratiotes* and *Eichhornia crassipes* are effective in reducing ammonia levels in tofu wastewater through the phytoremediation mechanism. *Pistia stratiotes* showed the highest efficiency at a weight of 600 grams with an ammonia reduction of 1.87 mg/L or 82.7%, while *Eichhornia crassipes* was most effective at a weight of 900 grams with a reduction of 1.95 mg/L or 86.5%. These results indicate that both types of plants have significant potential in wastewater treatment, with optimal efficiency depending on the type and weight of the plants used.

As a follow-up, small-scale tofu processing industries are recommended to utilize *Eichhornia crassipes* in wastewater holding ponds as a simple and environmentally friendly method to reduce ammonia levels before the wastewater is discharged into the environment. In addition, local governments through the Environmental Agency are expected to provide technical assistance to household-scale business operators regarding the implementation of this phytoremediation method. Further research also needs to be conducted to assess the effectiveness of combining aquatic plant species as well as the influence of other environmental factors such as retention time, pH, and lighting on the performance of ammonia reduction.

REFERENCES

1. Yadav Rambalak and PGS. Young Consumers' Intention towards Buying Green Products in a Developing Nation: Extending the Theory of Planned Behavior. 2016;
2. Alam JS, Lingkungan D, Rahadi B, Wirosoedarmo R, Harera a. Anaerobic-aerobic system on wastewater treatment of tofu industry to reduce level of BOD5, COD, and TSS.
3. Peraturan Menteri Lingkungan Hidup Dan Kehutanan Republik Indonesia Tentang Baku Mutu Air Limbah Domestik. 2016;
4. Arsalan. Studi Pengelolaan Limbah Cair Industri Tahu Di Desa Samili Kecamatan Woha Kabupaten Bima. 2019;
5. Pergub kalsel nomor 36 tahun 2008.
6. Bayu Avrianto Raksakadarma. Sosialisasi Pemanfaatan Limbah Cair Tahu Guna Mengurangi Pencemaran Lingkungan Di Desa Tegaldowo.

7. Sulistiyanto H. Perbedaan kadar Amonia Pada Air Limbah Berdasarkan Perlakuan Pengawetan Dan Lama Waktu Penyimpanan. Skripsi. 2018;
8. Akhir oleh T. Studi perbandingan kemampuan tanaman eceng gondok dan kangkung air dalam menurunkan cod dan amonia dari pengolahan lanjut biofilter anaerob media sarang tawon.
9. Amry Jaya P. Studi Perbandingan Kemampuan Tanaman Eceng Gondok Dan Kangkung Air Dalam Menurunkan COD Dan Amonia Dari Pengolahan Lanjut Biofilter Anaerob Media Sarang Tawon. 2018;
10. Nouri A. EA. T da SJA and MR. Assessment of yield, yield-related traits and drought tolerance of durum wheat genotypes (Triticum turjidum var. durum Desf.). 2011;
11. Rahadian R, Sutrisno E, Sumiyati S. Efisiensi Penurunan Cod Dan Tss Dengan Fitoremediasi Menggunakan Tanaman Kayu Apu (Pistia stratiotes L.) Studi Kasus: Limbah Laundry [Internet]. Vol. 6, Jurnal Teknik Lingkungan. 2017. Available from: <http://ejournal-s1.undip.ac.id/index.php/tlingkungan>
12. dan Sedimen Berdasarkan Tata Guna Lahan di Sekitar Sungai Banger Pekalongan Siska Setyowati P, Heru Suprpti dan Erry Wiryani N. Kandungan Logam tembaga (Cu) dalam Eceng Gondok (Eichhornia crassipes).
13. Cahyani M. Penurunan Konsentrasi Nikel (Ni) Total Dan Cod Menggunakan Tumbuhan Kayu Apu (Pistia Stratiotes L.) Pada Limbah Cair Elektroplating.
14. Fachrurozi M, Listiatie B, Utami D, Suryani F, Kesehatan M, Universitas A, et al. Pengaruh Variasi Biomassa Pistia stratiotes L. Terhadap Penurunan Kadar BOD, COD, dan TSS Limbah Cair Tahu Di Dusun Klero Sleman Yogyakarta.
15. Ahmad H, Adiningsih R, Lingkungan JK, Mamuju K. Efektivitas Metode Fitoremediasi Menggunakan Tanaman Eceng Gondok Dan Kangkung Air Dalam Menurunkan Kadar Bod Dan Tss Pada Limbah Cair Industri Tahu.
16. Ratnani RD, Ratnani RD, Kurniasari L, Teknik J, Fakultas K, Universitas T, et al. Pemanfaatan Eceng Gondok (Eichornia Crassipes) Untuk Menurunkan Kandungan COD Indah Hartati.
17. Sari lutfina indah. Kemampuan Eceng Gondok (Eichhornia sp.), Kangkung Air (Ipomea sp.), dan Kayuapu (Pistia sp.) Dalam Menurunkan Bahan Organik Limbah Industri Tahu(Skala Laboratorium).
18. Pramaningsih V, Wahyuni M, Ade DM, Saputra W, Studi P, Iii D, et al. Kandungan Amonia Pada Ipal Rumah Sakit Umum Daerah Abdul Wahab Sjahranie, Samarinda. Jukung J Tek Lingkung. 2020;6(1):34–44.
19. Efektifitas Subsurface Flow-Wetlands Dengan Tanaman Eceng Gondok Dan Kayu Apu Dalam Menurunkan Kadar COD dan TSS pada Limbah Pabrik Saus [Internet]. Available from: <http://lib.unimus.ac.id>
20. Cook Christopher. Aquatic and Wetland Plants of India. Oxford University Press.; 1994.
21. Febri Nurfitriana. Fitoremediasi Air Tercemar Timbal Pb.
22. Tunggal pridan prakoso. Fitoremediasi menggunakan tanaman air eceng gondok dan kayu apu dalam menurunkan kadar amoniak pada limbah cair karet. 2022;
23. Haryati M, Purnomo T, Kuntjoro S, Biologi J, Matematika F, Ilmu D, et al. Kemampuan Tanaman Genjer (Limnocharis Flava (L.)Buch.) Menyerap Logam Berat Timbal (Pb) Limbah Cair Kertas pada Biomassa dan Waktu Pemaparan Yang Berbeda.
24. Cunningham SD, Shann JR, Crowley DE, Anderson TA. Phytoremediation of Soil and Water Contaminants [Internet]. Vol. 04. UTC; 2023. Available from: <https://pubs.acs.org/sharingguidelines>
25. Wang HLS. A review on in situ phytoremediation of mine tailings. Chemosphere. 2017;

