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HYASORB: NaOH-Treated Water Hyacinth (*Eichhornia crassipes*) as a Biosorbent for Over-the-Counter Ibuprofen (Ibufen®) in Aqueous Solutions

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Abstract

This study developed a sustainable solution to two issues in the Philippine waterways: the invasive water hyacinth and Ibuprofen pharmaceutical pollution. The researchers created a biosorbent from water hyacinth by treating it with sodium hydroxide (NaOH) to absorb Ibuprofen from water. In the experiment, the team dried, blended, and soaked the water hyacinth in NaOH. They then tested different bio-sorbent masses (5g and 10g) and contact times (20 and 60 minutes) on an Ibuprofen solution. The findings indicated that the water hyacinth enhanced with NaOH was effective in removing Ibuprofen. The maximum removal rate was 52.59%, which was achieved with 10g of biosorbent after 60 minutes. The mass of the biosorbent was found to be more significant than the contact time. In conclusion, this study has been able to produce a sustainable biosorbent out of water hyacinth that will deal with the overpopulation of water hyacinth as well as the pharmaceutical pollution. This is a viable waste-to-wealth solution that provides the local communities with a clean environmental solution to their water quality issues and at the same time, take advantage of an invasive species to benefit themselves.

Keywords: Ibuprofen, Water Hyacinth (Eichhornia crassipes), NaOH Pretreatment, Wastewater Treatment, Low-Cost Sorbent

1. Introduction

The two primary challenges of biological invasion and chemical contamination are gradually threatening the freshwater eco-systems. In the Philippines, water bodies like Laguna Lake, Agusan Marsh, and river systems of Mindanao are under a continuous ecological pressure because of invasive aquatic macrophytes and the release of untreated wastewater (Koons, 2024). Some of the most common invasive species include

(Eichhornia crassipes) also referred to as Water hyacinth. Being originally indigenous to the Amazon Basin, the floating plant has become one of the most aggressive aquatic weeds in the world. It is able to multiply its biomass within weeks when it is given favorable nutrient conditions because of its rapid vegetative reproduction (Rezania et al., 2015). In the Philippine waterways, thick cover of water hyacinth disrupts the penetration of sunlight, decreases the dissolved oxygen, hinders fisheries, hinders navigation routes, poses high risks of flooding (Villamor et al., 2020). Mechanical removal and disposal of this invasive biomass consume a good deal of financial resources every year at local government units, but it has proven difficult to control in the long term.

At the same time, the increasing number of contaminant sources, especially the pharmaceutical residues have become a growing issue of environmental concern. The medications find their way into aquatic systems by sewage of residences, mostly found near hospitals, farm run-offs, and disposal of pharmaceuticals. The traditional wastewater treatment facilities do not target the elimination of most pharmaceutical substances, which means that traces of them are retained in effluents, which enter natural waters (Adewuyi, 2020). One of the most commonly used pharmaceutical pollutants across the globe is Ibuprofen a non-steroidal anti-inflammatory drug (NSAID), which is used in the treatment of pain, inflammation, and fever.

Ibuprofen is regarded as a pseudo-persistent pollutant due to the constant supply of it into the water bodies. In spite of the fact that it can degrade under some environmental conditions, its continuous output keeps its concentrations in the surface water measurable. Ecotoxicology research shows that even low concentration of ibuprofen could have negative effects on aquatic organisms (Lim, 2025). According to studies, ibuprofen is toxic to algae, daphnia, and fish and may interfere with reproduction and physiological processes (Cleuvers, 2003). Long-term exposure has the potential of disrupting endocrine systems and tampering with growth patterns among aquatic biota. Due to the dense population density in the Philippines, the general accessibility of over-the-counter medication and the possibilities of contamination of water systems in the country, the risk of pharmaceutical contamination to the local water systems is high.

Integrated environmental management has a rare chance in the coexistence of the invasive biomass accumulation and the pharmaceutical pollution. Instead of treating water hyacinth as a nuisance, it can be recycled into value added substance to re-move pollutants. This is in line with the idea of the circular economy which seeks to convert environmental liabilities into re-sources. Water hyacinth harbors cellulose, hemicellulose, lignin and other functional groups (hydroxyl -OH and carboxyl -COOH) that can react with organic and inorganic pollutants (De P Lima & Asencios, 2021). Such structural properties render it an attractive candidate in biosorption.

The process of a passive binding of contaminants to biological substances is referred to as biosorption (Gupta and Suhas, 2009). Biosorption has the merit over the more sophisticated treatment processes, including membrane filtration, ozonation or activated carbon adsorption, in terms of cost, availability and environmental friendliness. Plant biomasses were used to success-fully eliminate dyes, heavy metals, and organic pollutants in aqueous systems with the use of agricultural wastes (Adewuyi, 2020). There are however, comparatively less studies examining the utilization of modified water hyacinth to eliminate common over the counter drugs like ibuprofen.

Chemical modification improves the functioning of the biosorbent through the increase in surface area and the reactive functional groups. Treatment with sodium hydroxide (NaOH) is a well-known method of enhancing adsorption capacity. NaOH treatment breaks down the lignin structures, eliminates impurities, and

enhances porosity in lignocellulosic biomass (Osman et al., 2023). Alkali modification, in addition, increases the surface negativity and the availability of functional groups, making the bio-sorbent surfaces stronger in their interactions with organic molecules (Samaraweera et al., 2020). These chemical and structural enhancements will be anticipated to enhance adsorption efficiency.

Although the potential of biosorption has been documented there is a research gap in the localized study, at school level in conducting experimental verifications on the application of NaOH-treated water hyacinth in selective removal of ibuprofen under controlled laboratory conditions (International Journal of Advanced Research, 2020). The majority of studies published are centered on heavy metals or synthetic dyes whereas less are aimed to examine pharmaceutical adsorption under conditions that are pertinent to the Philippine waters. In addition, the combination of invasive species control and pharmaceutical pollution management is a topic of community research that has not been studied well.

To fill the gap, this study develops and assesses NaOH-treated water hyacinth biomass as a biosorbent in the aqueous solution in the extraction of ibuprofen. The study is based on a factorial experimental design to investigate the impact of biosorbent mass (5 g vs. 10 g) and contact time (20 min vs. 60 min) on the efficiency of removal. The study will answer the question of whether higher dosage and longer exposure will increase the adsorption performance through the use of Two-Way ANOVA statistical analysis and UV-Visible spectrophotometric analysis.

This study contends that sustainable waste-to-wealth solution involves the transformation of an invasive weed that grows in aquatic environments and converting it into a low-cost biosorbent, basically solving a problem using a problem. The research will add to the environmental sciences education, the local water management policies, as well as the larger debate on sustainable wastewater treatment options in developing nations. Finally, it shows that locally found biomass can be applied to global-level problems of emerging pollutant elimination.

2. Methods

This section details the procedures, materials, and methods used for the preparation, creation, and testing of sodium hydroxide (NaOH)-enhanced water hyacinth (Eichhornia crassipes).

2.1. Collection of Materials

Newly harvested water hyacinth plants (Eichhornia crassipes) were obtained from Alvareda, Asuncion and immediately brought to the Provincial Agriculture Office (PAGRO) for identification. Certification of the plant used was given (Certificate of Authentica-tion). The reagents and chemicals for the experiment were water hyacinth, sodium hydroxide (NaOH) solution, ibuprofen (Ibufen) tablets, pure ethanol and distilled water. The cheesecloth used for filtration is bought from Gaisano Mall of Tagum and the filter paper, laboratory gloves was obtained from MedTools Tagum. (400 mg Ibufen) were purchased from a community drugstore in Tagum City.

2.2. Preparation of Water Hyacinth Biomass

Two kilograms of fresh water hyacinth were firstly made ready to be utilized as a biosorbent. This was initiated by reducing the manual size of the total amount of collected biomass that was reduced into about

3-5 cm each piece. This is an important first step which was done to give the material a large surface area thus speeding up the other drying processes.

Once the pieces of plants were cut into smaller sizes, they were taken through two drying processes in order to eliminate as much moisture as possible. The pieces were initially spread in the sun for 6 hours. After that, they were put in an oven and dried in small-batches, approximately 20 to 40 minutes. This varying drying period ensured that all the sections of the plant, regardless of its thickness, dried evenly (Osman et al., 2023).

In order to dehydrate the material fully and to make sure that all moisture was evaporated, the material dried in the oven was subjected to another round of 4 hours under the sun. This was necessary in order to get rid of any moisture that was remaining and make the biomass ready to be ground but it would also help to limit the chances of a clumping or poor quality of material in the case of storage.

The last step was the preparation of the physical form of the adsorbent. The totally dry, brittle water hyacinth was crushed and made into a fibrous texture through a home blender. The mechanical grinding procedure resulted in a product that was not fully powdered, as it is the necessary physical condition to use the full potential of the effective surface area of the subsequent chemical modification to the sodium hydroxide (NaOH) solution (Puja et al., 2019).

2.3. Pretreatment of Water Hyacinth

The water hyacinth was prepared and grounded properly and then soaked in a solution of sodium hydroxide (NaOH) within 24 hours. A 24 hour period of soaking with the solution of NaOH was taken with the biosorbent. Such a treatment is a significant measure towards improving the performance of the biosorbent. The base is mainly effective in breaking down the rigid lignin and hemicellulose segments of the plant fibers which serve the purpose of exposing and enhancing the surface area that the adsorption can have. It further introduces or reacts chemical functional groups such as hydroxyl (-OH) and carboxyl (-COOH) to the sur-face to enable the material to interact further with ibuprofen molecules in water (Samaraweera et al., 2020).

2.4. Pulverization of Ibuprofen Tablets

Ibuprofen tablets (Ibufen) were acquired commercially and utilized as the source of the absorbate in the study. The 4 pills were crushed in a mortar and a pestle into a fine homogenous powder of 400mg of ibuprofen. In this powder, 200 mg of the powder was weighed with care under each treatment using a precision balance. The weighted samples were further divided into ten clean Erlenmeyer 500mL flasks with constant mass and manipulation across the experimental set ups.

2.5. Preparation and Filtration of Ibuprofen Solution

Powdered ibuprofen was poured into the ten Erlenmeyer flasks with 20 mL pure ethanol in order to dissolve it. The solvent was ethanol since the solvent can easily dissolve ibuprofen and produce a smooth and even solution without altering the inherent properties of ibuprofen (Watkinson et al., 2009). This was done with clean glass rod and the mixtures were stirred and made homogenous until the ibuprofen had completely dissolved. Each mixture was filtered with filter paper with the assistance of a separatory funnel to eliminate any tablet fillers or binders which were not dissolved. The resulting colourless liquid that was used to pass through the filter was used as the solution of ibuprofen to continue with the adsorption experiments.

2.6. Experimental Setup

The ready aliquots of ibuprofen in Erlenmeyer flasks were added to the treated samples of water hyacinth. Already, 10 g of bio-sorbent was placed in four flasks, another four flasks received 5 g, and the other two received none and acted as controls. All the flasks were filled up with distilled water up to the volume of 500 mL, as per the set-up in the experiment. The masking tape and permanent marker were used to label each flask appropriately to avoid confusion of the treatments and to ensure that there was proper monitoring of the flasks during the experiment.

Table 1: Experimental Groups

Treatment Number	Ibuprofen Concentration	Biosorbent Dosage	Contact Time
1	200mg/500mL	5 g	20 min
2	200mg/500mL	10 g	20 min
3	200mg/500mL	5 g	60 min
4	200mg/500mL	10 g	60 min
5 (control)	200mg/500mL	water	-

2.7. Adsorption Process

Once the experiment was arranged, a clean glass rod was used to stir the contents of each Erlenmeyer flask to ensure that the ibuprofen solution and the biosorbent were mixed well. All the mixtures were stirred throughout the entire contact time to ensure that the ibuprofen was well interacting with the biosorbent surface. The experiment was conducted at the ambient temperature and each setup stirred on the basis of the given contact time (Monash & Pugazhenthi, 2009).

The mixtures were filtered after completion of the set contact times to separate the biosorbent and the liquid. One of the ways this was done was by filtration using clean cheesecloth and separatory funnel in order to ensure good separation of the liquid. Filtering was followed by parafilm cover on each flask to prevent contamination and evaporation and wrapping of aluminum foil to avoid light. The samples filtered were marked and kept to be further tested using UV Vis-spectrophotometer.

2.8. Sample Transport & Spectrophotometric Analysis

The filtrates were then filtered and safely wrapped in clean cloth layers and put in a well-built box to guarantee stability and pre-vent spillage during transportation. The samples were then taken to WVN Research Laboratory in Davao City where the UV-Visible spectrophotometric analyses were performed to identify the amount of ibuprofen that remained in each solution at the end of biosorption.

2.9. Waste Disposal

Any remaining materials like used water hyacinth, used filter papers, and ethanol remnants were taken and discarded in accordance with the usual lab waste disposal regulations. Any wastes which contained residual traces of ibuprofen or ethanol were put in special chemical waste containers to be handled and disposed of by the trained personnel. As reusable substances were the glassware and other items, they were

washed using distilled water and detergent and allowed to dry in air before being put back. The laboratories were also cleaned and disinfected to avoid contamination, and ensure that the lab is safe and organized.

2.10. Data Analysis

The data obtained were all analyzed with the help of Two-Way ANOVA to determine the influence of biosorbent quantity and contact time on ibuprofen removal. Every test was repeated (n = 2) and the data was presented as Mean +- SD. The p-value of less than 0.05 was employed to demonstrate whether there were any significant differences between the groups. Despite the weaknesses brought about by the small number of replicates with respect to the strength of inferences, the two-way ANOVA, gave a valid ground to the identification of interaction effects and controlling factors of main influence on the adsorption performance.

3. Results

3.1. Mean Final Concentration and Removal Efficiency

Table 2 contains the values of absorbance and final concentrations (at 290 nm) of each of the samples. Mean initial concentration (C0) was calculated on the control replicates (Treatment 5) and applied to calculate efficiencies of removals.

Table 2: Raw Data

Test Samples	Results	
	Absorbance @ 290nm	Concentration, ug/ml
T1A 5g 20M	0.321	703.9
T2A 10g 20M	0.241	528.5
T1B 5g 20M	0.344	754.4
T2B 10g 20M	0.214	469.3
T3A	0.321	703.9
T3B 5g 60M	0.255	559.2
T4A 10g 60M	0.201	440.8
T4B 10g 60M	0.201	440.8
T5AC	0.423	927.6
T5BC	0.425	932.0

The mean initial concentration used as a baseline was:

$$Co = \text{mean of treatment 5 replicates} = 927.6 + 932.0 / 2 = 929.8\ \mu g\ mL^{-1}$$

3.2. Standard Deviation

The removal efficiency for each treatment was calculated using:

$$\% \text{ Removal} = Co - Ce / Co \times 100$$

Where, Co=Initial Concentration, Ce= Final Concentration.

Descriptive statistics (mean ± SD) for final concentration and removal percentage for Treatments 1–4 (factorial experiment) are presented in Table 3.

Table 1: Descriptive statistics for Treatments 1–4 (n = 2 replicates per treatment)

Treatment	Mass (g)	Time	n	Mean Ce (μgmL^{-1})	SD Ce (μgmL^{-1})	Mean Removal	SD Removal
T1	5	20 min	2	728.15	35.71	21.58%	3.84%
T2	10	20 min	2	498.90	41.86	36.34%	4.50%
T3	5	60 min	2	631.35	102.32	32.08%	11.00%
T4	10	60 min	2	440.80	0.00	52.59%	0.00%

The results in Table 3 show that Treatment 4 had the lowest residual concentration (mean Ce=440.8μgmL^{-1}) and the highest removal efficiency, while treatment 2 also had similar effects, suggesting a correlation between mass and removal efficiency.

3.3. Two-Way ANOVA and Interaction Detail

A Two-Way ANOVA was conducted to assess the main effects of Biosorbent mass (5 g vs 10 g) and Contact time (20 min vs 60 min) on the dependent variable final concentration. The factorial data included only Treatments 1–4 (n = 8 total observations). The control (Treatment 5) was excluded from ANOVA but used to compute Co.

Table 4. Two-Way ANOVA summary (dependent variable: final concentration)

Source	Sum Sq	df	F	p(PR(>F))
Mass - 5g vs 10g	88620.50	1	26.2648	0.00686
Time - 20 min vs 60 min	12121.25	1	3.5924	0.13094
Mass x Time (interaction)	780.13	1	0.2312	0.65575
Residual (error)	13496.49	1	—	—

Partial eta squared η^2p was computed for each effect using:

η^2p = SSeffect / SSeffect + SSerror

- Mass: $\eta^2p = 0.868$ (very large effect)
- Time: $\eta^2p = 0.473$ (moderate effect)
- Interaction: $\eta^2p = 0.055$ (small effect)

3.4. Visual Representation of Results

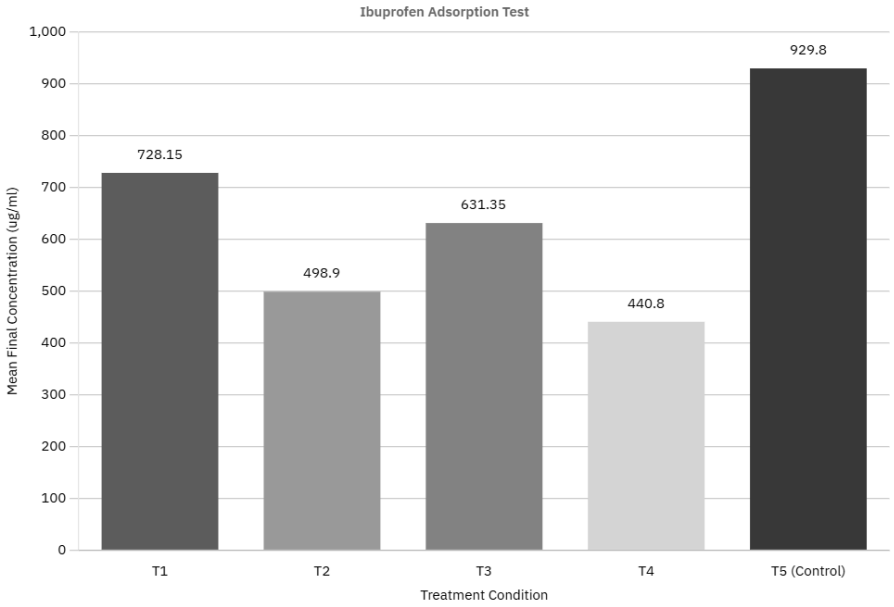


Figure 1. Ibuprofen Adsorption Test

The figure presents the trends summarized in Tables 2 and 3. Treatment 4 showed the shortest bar, indicating the lowest residual concentration and the highest removal efficiency. Treatment 2 followed, showing the second highest removal efficiency. Treatments 1 and 3 showed lower removal percentages, with Treatment 3 achieving slightly higher removal than Treatment 1 despite having the same biosorbent mass.

3.5. Post-hoc Comparisons

Tukey HSD pairwise comparisons (family-wise error corrected) on the treatment groups (T1–T4) are shown below.

Table 5. Tukey HSD pairwise comparisons (mean difference in final concentration)

Comparison	Mean difference (μg mL^{-1})	p-adj	95% CI lower	95% CI upper	Significant?
T1 vs T2	−230.25	0.0544	−466.71	6.21	No(marginal)
T1 vs T3	−97.60	0.4358	−334.06	138.86	No
T1 vs T4	−288.35	0.0258	−524.81	−51.89	Yes
T2 vs T3	132.65	0.2448	−103.81	369.11	No
T2 vs T4	−58.10	0.7585	−294.56	178.36	No
T3 vs T4	−190.75	0.0965	−427.21	45.71	No

The post-hoc test indicates Treatment 4 (10 g, 60 min) produced significantly lower final concentrations than Treatment 1 (5 g, 20 min) at the $\alpha = 0.05$ level (mean difference ≈ 288.35 μg mL^{-1}, $p = 0.0258$). Other

pairwise contrasts are not statistically significant after correction for multiple comparisons.

4. Discussion

This study compared the adsorption ability of the biosorbents, the statistical significance, and the effect of biosorbent dosage and contact time on the removal performance so as to identify the treatment that optimized the maximum removal efficiency of the biosorbent**.**

4.1. Mean Final Concentration and Removal Efficiency

The findings revealed that NaOH-treated Water Hyacinth was efficient in reducing ibuprofen concentration in aqueous solution with the greatest removal efficiency (52.59) at 10g biosorbent and 60 minutes. It means that the higher the dose of bio-sorbent, the better adsorption will be carried out due to the availability of more binding sites and surface area. Water hyacinth has lignocellulosic materials that have functional groups that include -OH and -COOH interacting with organic pollutants (Carneiro et al., 2022). The pretreatment of NaOH was probably beneficial to adsorption by enhancing porosity and unveiling more reactive sites (Osman et al., 2023; Samaraweera et al., 2020).

The observed trend is in line with the adsorption laws whereby an increase in dosage of adsorbent enhances better cleaning of contaminants because of a decrease in competition of adsorbent sites (Meftah et al., 2025). Though this was not totally eliminated, a reduction by over half the concentration of ibuprofen is still of importance to the environment, as it has been reported to be toxic to aquatic life (Cleuvers, 2003). This justifies the possibility of modified water hyacinth as a low-cost treatment solution in Sustainable Development Goal 6 (Clean Water and Sanitation).

4.2. Descriptive Statistics

Descriptive analysis showed that longer contact time slightly enhanced removal efficiency such that 60-minute treatments were better than 20-minute treatments when using the same dosage. This implies that adsorption is time-dependent whereby there is an initial rapid stage of surface binding then slower diffusion into the internal pores (Monash & Pugazhenthi, 2009). The effect of time was however smaller than that of the biosorbent mass.

This is confirmed by the fact that the performance of the 10 g treatments has been consistently higher, which explains the fact that dosage is the predominant factor affecting removal efficiency. Higher mass of biosorbents offers greater active sites and re-tards saturation resulting in increased uptake of contaminants (Meftah et al., 2025). The relatively steady findings of high dosage treatment can also indicate the enhanced surface modification of NaOH treatment (Osman et al., 2023).

4.3. Two-Way ANOVA

The Two-Way ANOVA revealed statistically significant impact of biosorbent mass on the final concentration of ibuprofen ($F(1,4) = 26.26$, $p = 0.0069$), as the rise in dosage (5 g to 10 g) led to a significant decrease in the residual concentration. This is in line with the adsorption theory where the larger the amount of adsorbent, the larger the number of binding sites (Gupta and Suhas, 2009). The significant effect size also demonstrates that the most critical factor contributing to the performance of adsorption was mass.

Conversely, the contact time was not statistically significant at = 0.05 (p = 0.131) but it had a positive trend. The insignificance might be conditioned by small sample size. The non-significant interaction indicates that mass influences removal without moderate variations in time, and dosage optimization is the most important operational strategy.

4.4. Tukey HSD Post-Hoc Test

The Tukey HSD test revealed that only the Treatment 1 (5 g, 20 min) and the Treatment 4 (10 g, 60 min) were significantly differ-ent (p = 0.0258), with a difference in Means of 288.35mg mL-1. This affirms the fact that the greatest adsorption performance is obtained with increased dosage and the prolonged duration of contact.

The rest of the comparisons were not statistically significant, which means that minor changes in either of the factors might not lead to a drastic change in the outcomes. Practically, a higher mass of biosorbent can be more readily increase than prolonging the treatment period because water hyacinth is easily available in the Philippines (Villamor et al., 2020). The application of this invasive species as a biosorbent contributes to environmental safety and enhances SDG 6 with the help of sustainable water treatment systems.

5. Conclusion

This study has been able to show that water hyacinth (Eichhornia crassipes), one of the species that are often classified as a big ecological problem to Philippine rivers and lakes can be reused in a systematic manner in order to address a second ecological emergency. The researchers successfully reduced this invasive biomass into a useful, inexpensive biosorbent using the strategic addition of sodium hydroxide (NaOH), which could remove, via the addition of sodium hydroxide, pharmaceutical contamination in the aqueous environment-in this case, of over-the-counter Ibuprofen. The effectiveness of such waste-to-wealth strategy is confirmed by the great results obtained in experiments, and data processing indicates that the amount of biosorbent used in the treatment process is the most significant factor that determines the success of adsorption. The maximum performance was not-ed in the experimental design that was used in which 10 grams of NaOH-treated water hyacinth were added to the Ibuprofen solution and a 60-minute contact was allowed. The maximal removal rate of the system under these conditions was 52.59, which means that the dosage and the time of interaction also lead to a large increase in the ability of the material to immobilize pharmaceutical molecules in its fibrous network.

In addition to the direct laboratory findings, the work creates the fact that NaOH-enriched water hyacinth is an efficient, ecologically-friendly, and sustainable resource. It provides a twofold ecological management approach: on the one hand, combating the excessive population of the invasive plant population, and, on the other hand, the increasing danger of the pharmaceutical emergent pollutants of water bodies. It offers a clean, affordable water treatment method to the local communities especially around agricultural and urban centers in the Philippines, where costly, traditional water treatment methods are prohibitive. Finally, this study can be viewed as a feasible roadmap toward turning an environmental liability into a community resource to enhance a cleaner aquatic ecosystem and encourage the innovative exploitation of local natural resources. This study attains this unique and sustainable objective of using a problem to solve a problem by adapting an invasive aquatic weed to eliminate a pharmaceutical runoff.

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