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Phytoremediation potential of *Equisetum hyemale* in diverse waste management: A decade-long literature synthesis on water Bamboo's role in industrial and domestic effluent treatment

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ABSTRACT

Escalating waste production due to population growth and diverse community activities poses environmental and public health threats. To mitigate these effects, this study investigates using water bamboo (*Equisetum hyemale*) in phytoremediation. A comprehensive literature review was conducted, analyzing articles from 2011-2024 from Indonesian language journals. Ten articles were selected, focusing on the phytoremediation of four types of waste: tofu industry waste, leachate, domestic waste, and lead. Findings reveal water bamboo's potential as a phytoremediation agent, effectively reducing waste levels in various contexts. For instance, it reduced BOD, COD, and TTS in tofu industry waste; Pb, Zn, Cr, DO, and pH in leachate waste; BOD, COD, and detergent levels in domestic waste; and lead in lead (Pb) industrial waste. The study underscores the potential of water bamboo in real-world liquid waste management applications, contributing to sustainable waste management strategies and addressing environmental and public health challenges.

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Introduction

The burgeoning global population and the escalating diversity of human activities have precipitated a multifaceted increase in societal needs. This surge has led to an exponential increase in waste generation, encompassing liquid, solid, and gaseous forms[1-3]. This burgeoning waste threatens environmental sustainability and poses significant risks to public health, particularly in densely populated areas[4,5]. The phenomenon of leachate, a liquid pollutant resulting from water percolating through waste, exemplifies the urgent need for effective waste management practices. The complexity of wastewater, which includes a wide range of organic and inorganic pollutants, microorganisms, and soluble and insoluble contaminants, is a pressing concern that demands rigorous regulatory oversight and innovative treatment solutions[6,7].

Technological advancements have shed light on various waste management strategies, focusing on their effectiveness, efficiency, and environmental impact. Among these, phytoremediation is a sustainable and cost-effective approach, utilizing plants and their associated microbial communities to sequester and degrade pollutants[8,9]. However, despite the recognized potential of phytoremediation, there is a notable gap in research regarding the

optimization of these biological systems and their application on a larger, more impactful scale[10].

The water bamboo plant (*Equisetum hyemale*), known for its ornamental value and modest size, has demonstrated a remarkable capacity for pollutant absorption. Its ability to bind pollutants through its roots and collaborate with microorganisms in water positions it as a viable candidate for phytoremediation. Yet, the literature reveals a scarcity of comprehensive studies on the plant's translocation mechanisms and the fate of pollutants within its system[11].

This article aims to provide a theoretical foundation supporting resolving these identified gaps. By thoroughly reviewing the current state of knowledge and highlighting areas lacking in-depth research, we seek to guide future studies toward a more complete understanding of phytoremediation processes, particularly those involving hyperaccumulator plants like water bamboo.

This work aspires to contribute to the scientific community by offering a detailed theoretical backdrop for upcoming research endeavors. It is intended to serve as a stepping stone for researchers, enabling them to approach the problem of waste management with a scientifically sound framework and to build upon the collective knowledge base with novel insights into the field of phytoremediation.

Method

The method used in this research is a literature study by analyzing several articles and then reviewing documents evaluating previous research. Several stages of the literature review method: (1) Selection of manuscripts, (2) Articles that have been obtained according to the relevance of the subject matter of the literature review, articles originating from Google Scholar related to phytoremediation of liquid waste using water bamboo (*Equisetum hymale*), (3) Articles used in the last 14 years from 2011-2024, (4) Articles researched from Indonesian language journals (5) This article focuses on the potential of water bamboo as a phytoremediation agent in tofu, leachate, domestic and lead industrial wastewater with a total of 10 articles (6)) Monitoring of titles and abstracts, the articles that have been selected are checked and researched whether they are by the objectives of the research being carried out (6) Research analysis uses qualitative content with a correlation between content and context, as a research method it can use knowledge related to the issue and topic being analyzed[12]. This research is a qualitative type through literature study. One of the research stages is collecting primary library sources in the form of scientific journal articles, Proceedings, or secondary literature[13].

Results and Discussion

This study investigates the efficacy of water bamboo (*Equisetum hymale*) as a phytoremediation agent in reducing various types of liquid waste. It synthesizes findings from peer-reviewed scientific articles published over the past 14 years, ensuring that only validated data is included. The research categorizes the collected data according to the specific type of liquid waste treated by water bamboo (*Equisetum hymale*). This categorization is systematically displayed in the following Table 1, facilitating a clear and comprehensive understanding of the phytoremediation capabilities of this plant species.

Table 1. Phytoremediation water bamboo in variate liquid waste

Liquid waste	Researcher	Count research
Tofu industrial waste	Al Kholif et al.[14]; Riyanto[9]	2
Leachate liquid waste	Anam MS et al.[15]; Widyastuti et al.[3]; Suharto et al.[11]; Mumtahanah et al.[16]	4
Household waste	Margowati & Abdullah[17]; Wulandari & Hartini[18]	2
Pb waste	Triastianti et al.[19]; Ajeng & Wesen[20]	2

Tofu Industry Waste is one of the wastes that contributes to water pollution, many tofu industry factories dump the waste products from the tofu making process directly into the environment without prior waste management[9]. This tofu industry waste can be in the form of solids and liquids. In the article we reviewed related to tofu industry waste, namely liquid waste. This waste is very worrying because there is a lot of waste from the tofu home industry which is close to residential areas[9,14]. The impact is in the form of a strong odor, which has the potential for residents' health or water availability because this waste can pollute water, especially wells.

Regulation of the Minister of Environment of the Republic of Indonesia Number 5 of 2014 concerning Wastewater Standards explains that there are levels of wastewater quality standards that must be met before being discharged into the environment. There is a solution related to waste management using the phytoremediation method of aquatic bamboo plants[9,14], this aquatic bamboo plant is able to absorb high concentrations of waste pollutants, namely toxic compounds and organic substances. There is a need for supervision in the use of plants in wastewater treatment because of the rapid growth of plants due to excessive waste content[9].

In the phytoremediation of water bamboo plants on tofu industry waste, the average BOD was reduced by 813.33 mg/L with an initial treatment of 4860 mg/L so that the effectiveness of this water bamboo plant was 16.73%[9]. Apart from that, water bamboo can reduce COD and TTS levels, with initial COD treatment of 3670.88 mg/L and TSS of 686.67 mg/L. The effectiveness of aquatic bamboo plants in reducing COD is 90.59% and is able to eliminate COD levels in tofu industry waste[14]. Meanwhile, the effectiveness of reducing TTS is 40%[14].

Water Bamboo is easy to care for and resistant to external influences, making it suitable for use as a phytoremediation plant, its stems have a high silicate content which is absorbed by the roots. The photosynthesis process occurs with high oxygen release in the water which is used by aquatic biota in decomposing waste water[9]. During treatment, water bamboo begins to experience physical changes that decrease, this is caused by the acid in the waste. Apart from that, the planting media also has an influence, due to the absence of planting media there is no help to maximize waste decomposition[9,14]. For maximum results, management is carried out first before entering the management reactor.

This leachate waste contains levels of Nitrogen (N), Calcium (Ca), Magnesium (Mg), Iron (Fe) and Potassium (K). Heavy metals in the initial leachate waste were 0.38932 ppm Chromium (Cr) and 2.2923 ppm Lead (Pb)[9,11,15,16]. However, leachate exceeds the quality standards stated in the Government Regulation of the Republic of Indonesia no. 82 of 2001, namely that the content must not exceed 0.1 ppm for Pb and 0.05 ppm for Cr with an effectiveness value of 82.2% in batch phytoremediation systems[15]. There is Zn waste that is still above the leachate quality standard threshold, so it is not safe to throw it directly into the community. This water bamboo plant is a hyperaccumulator because it is easy and can grow in water that has a high level of regression. Changes in water bamboo plants that are exposed to heavy metals are roots so that root growth is hampered in length, but this also depends on the roots themselves in the metabolism of root formation. The effectiveness of reducing leachate levels was maximum on the 9 day with 80.9%, so the plant residence time also affects the phytoremediation of water bamboo plants[3].

Aquatic bamboo plants remove organic pollutants in three ways: (1) absorb pollutants, (2) accumulate non-phytotoxic metabolism in plant cells (3) release exudates and enzymes that stimulate microbial activity and absorb minerals in the rhizosphere region. Plants in general can remove pollutants when they reach maturity. Water-based bamboo stems are high in silicate, which helps bind metal particles absorbed by plant roots[9,11,15,16]. Leachate waste with an age of 2 years, with a dark color, strong odor and has little oil and very high TDS. Aquatic bamboo plants will be able to remediate pollutants when the plants have reached maturity. Effectiveness value of aquatic bamboo plants in reducing Cd and Pb 70-75%[11].

This leachate water has a waste that is considered acidic with a value of 6. In the bamboo phytoremediation process, the water has increased by around 0.6 to 6.6. This is

because the decomposition process of organic material takes place more quickly in neutral pH conditions and alkaline. The solubility of oxygen in water will decrease if temperature and salinity increase, dissolved oxygen in water will also decrease due to decay and respiration from animals and plants which is then followed by an increase in free CO_2 and a decrease in pH. The increase in DO increases, so it can be said that this water bamboo plant is effective[16].

Domestic liquid waste is usually disposed of in public waters and is included in the gray water category for community use. This anionic cleaner has strong cleaning power, is cheap and easy to obtain locally. Although the alkyl groups are rapidly degraded and the original surfactant is lost, the polyethylene groups remain for a long time and these remaining groups are toxic to aquatic life. Bamboo Air can manage and reduce both dissolved and insoluble content in domestic liquid waste[17,18].

The efficiency of phytoremediation of aquatic bamboo plants (*Equisetum hymale*) in reducing BOD and COD levels can reduce BOD and COD with varying treatment weights and residence times. The effectiveness of this water bamboo on BOD is around 85% and COD 75%[17]. Aquatic bamboo plants perform very well in domestic wastewater treatment using underground constructed wetland systems (SSF-wetlands). When stored in the reactor for 6 days, the reduction rate reached 99.91%[18]. Phytoremediation plants, their stems have a high silicate content which is absorbed by the roots.

Pollution caused by lead (Pb) can enter the human body through the air, through food consumed every day, even from water bodies, and lead (Pb) can be absorbed into the air with the help of rainwater. lead (Pb) (tin) enters the water either directly or through the corrosion process of mineral rocks[19,20]. The nervous system effects caused by lead (Pb) were highlighted in the Occupational Health Study, which found that workers exposed to high levels of lead experienced anorexia, eating disorders, depression, fatigue, headaches, and people reported symptoms such as forgetfulness, dizziness[19].

Water bamboo after 3 days with high lead (Pb) concentrations showed signs of lead metal stress at a holding time of 3 days/72 hours. Because the existing lead can be combined well by plants, lead metal can be absorbed by aquatic bamboo plants, stored as food reserves, and then released into the surrounding air in the form of crystals. Effectiveness of water bamboo in waste phytoremediation 21.26%[19].

After phytoremediation was carried out for 10 hours, the ability of water bamboo stems to process lead content worked effectively. Apart from that, it is also based on the type of solution that is processed, namely lead (Pb) solution, water bamboo. Plants are included in the type of plant extracts. That is, plants that absorb pollutants through their roots and transfer them to their stems and leaves[19,20]. Here it is processed into H_2O in the stems and leaves, or also used in the photosynthesis process, the food preparation process carried out by plants. Water bamboo absorbs waste contents through its roots, and the roots use silicate fluid produced by Sclerenchyma fibers to bind the waste contents in the stem and turn it into an artificial solution. Combining lead content. Effectiveness of water bamboo plants aged 30 days; water bamboo can remove 76% lead (Pb) content with a flow rate of 200 ml/minute[20].

Phytoremediation, an environmentally friendly method, has shown promise in addressing water pollution issues caused by industrial activities like the tofu industry. Discharging untreated liquid waste from tofu production poses significant environmental and health risks due to its high pollutant content[21,22]. In this context, the use of aquatic plants, such as water bamboo (*Equisetum hymale*), has been explored as a solution to remediate the wastewater effectively[21,22]. Water bamboo has demonstrated the ability to reduce levels of pollutants like BOD, COD, TTS, heavy metals, and organic compounds in tofu industry waste, making it a suitable candidate for phytoremediation[21,22].

Studies have highlighted the effectiveness of water bamboo in reducing pollutant levels, such as lead (Pb), chromium (Cr), and other heavy metals, exceeding regulatory standards[21,23-25]. Water bamboo's capacity to absorb pollutants through its roots, accumulate them in stems, and release them into the air after transformation showcases its potential in waste treatment[23,26]. Additionally, the high silicate content in water bamboo stems aids in binding metal particles, contributing to the plant's efficiency in pollutant removal[21,23-25].

Furthermore, the pH levels of the wastewater play a crucial role in the phytoremediation process, with neutral to alkaline conditions favoring organic material decomposition and oxygen solubility[22]. Water bamboo's ability to thrive in varying pH conditions and release oxygen during photosynthesis enhances its effectiveness in treating acidic waste[22]. The adaptability of water bamboo to external influences and its ease of care makes it a practical choice for phytoremediation applications[21].

Conclusion

The potential of *Equisetum hymale* (water bamboo) in phytoremediation, particularly in treating tofu industry waste, is evident from its ability to reduce pollutant levels effectively. By harnessing the natural capabilities of aquatic plants like water bamboo, industries can mitigate the environmental impact of their activities and work towards sustainable waste management practices.

References

1 Hamilton, S. F., Sproul, T. W., Sunding, D. & Zilberman, D. Environmental policy with collective waste disposal. *Journal of Environmental Economics and Management* **66**, 337-346 (2013). https://doi.org:10.1016/j.jeem.2013.04.003

2 Amasuomo, E. & Baird, J. The concept of waste and waste management. *Journal of Management and Sustainability* **6** (2016). https://doi.org:10.5539/jms.v6n4p88

3 Widyastuti, D., Suprayitno, D. & Rahardjo, P. P. Potensi bambu air sebagai tanaman hiperakumulator logam berat Zn pada Leachate menggunakan metode fitoremediasi. *Jurnal Green House* **2**, 32-37 (2023).

4 Hansted, F. A. S., Mantegazini, D. Z., Ribeiro, T. M., Goncalves, C. E. C. & Balestieri, J. A. P. A mini-review on the use of waste in the production of sustainable Portland cement composites. *Waste Manag Res* **41**, 828-838 (2023). https://doi.org:10.1177/0734242X221135246

5 Langa, C. *et al.* Dynamic evaluation method for planning sustainable landfills using GIS and multi-criteria in areas of urban sprawl with land-use conflicts. *PLoS One* **16**, e0254441 (2021). https://doi.org:10.1371/journal.pone.0254441

6 Ahmad, A., Priyadarshani, M., Das, S. & Ghangrekar, M. M. Role of bioelectrochemical systems for the remediation of emerging contaminants from wastewater: A review. *J Basic Microbiol* **62**, 201-222 (2022). https://doi.org:10.1002/jobm.202100368

7 Mramba, A. S., Ndibewu, P. P., Sibali, L. L. & Makgopa, K. A review on electrochemical degradation and biopolymer adsorption treatments for toxic compounds in pharmaceutical effluents. *Electroanalysis* **32**, 2615-2634 (2020). https://doi.org:10.1002/elan.202060454

8 Stepniewska, Z. & Kuzniar, A. Endophytic microorganisms--promising applications in bioremediation of greenhouse gases. *Appl Microbiol Biotechnol* **97**, 9589-9596 (2013). https://doi.org:10.1007/s00253-013-5235-9

9 Riyanto, A. Fitoremediasi Kayu Apu, Eceng gondok, dan Bambu air untuk menurunkan kadar BOD air limbah pabrik tahu. *Jurnal Ilmu Kesehatan Masyarakat* **12**, 162-170 (2023). https://doi.org:10.33221/jikm.v12i02.2360

10 Genchi, G., Sinicropi, M. S., Lauria, G., Carocci, A. & Catalano, A. The effects of cadmium toxicity. *Int J Environ Res Public Health* **17** (2020). https://doi.org:10.3390/ijerph17113782

11 Suharto, B., Susanawati, L. D. & Wilistien, B. I. Penurunan kandungan logam PB dan CR Leachate melalui fitoremediasi bambu air (*Equisetum Hyemale*) dan zeolit. *Agrointek : Jurnal Teknologi Industri Pertanian* **5**, 148-158 (2011).

12 de Albuquerque, J. P., Diniz, E. H. & Cernev, A. K. Mobile payments: a scoping study of the literature and issues for future research. *Information Development* **32**, 527-553 (2014). https://doi.org:10.1177/0266666914557338

13 Landmark-Hoyvik, H. *et al.* The genetics and epigenetics of fatigue. *PM R* **2**, 456-465 (2010). https://doi.org:10.1016/j.pmrj.2010.04.003

14 Al Kholif, M., Istaharoh, I., Pungut, S. J. & Widyastuti, S. Penerapan teknologi fitoremediasi untuk menghilangkan kadar COD dan TSS pada air buangan industri tahu. *Al-Ard J. Tek. Lingkung.* **6**, 77–85 (2021).

15 Anam MS, M. M., Kurniati, E. & Suharto, B. Penurunan kandungan logam Pb Dan Cr Leachate melalui fitoremediasi bambu air (Equisetum hyemale) dan Zeolit. *Jurnal Keteknikan Pertanian Tropis dan Biosistem* **1**, 43-59 (2013).

16 Mumtahanah, M., Pujiati, P. & Primiani, C. N. in *Seminar Nasional Sains dan Teknologi* Vol. 1 103-109 (2017).

17 Margowati, D. & Abdullah, S. Efisiensi fitoremediasi tanaman bambu air (*Equisetum hyemale*) dalam menurunkan kadar BOD dan COD air limbah rumah tangga di Desa Kracak Kecamatan Ajibarang Kabupaten Banyumas tahun 2016. *Buletin Keslingmas* **35**, 316-321 (2016). https://doi.org:10.31983/keslingmas.v35i4.1679

18 Wulandari, F. & Hartini, E. Pengolahan limbah cair rumah tangga menggunakan tanaman bambu air (*Equisetum Hyemale*). *ISIKES: Jurnal Kesehatan Masyarakat* **15** (2016).

19 Triastianti, R. D., Nasirudin, N. & Gregorius, G. Uji efektivitas penyerapan timbal (PB) menggunakan tanaman *Typha orientalis*, *Einchornia Crassipes* dan *Equisetum Hyemale*. *Jurnal rekayasa Lingkungan* **23**, 88-96 (2023).

20 Ajeng, A. B. & Wesen, P. Penyisihan logam berat timbal (Pb) dengan proses fitoremidiasi. *Envirotek : Jurnal Ilmiah Teknik Lingkungan* **5**, 17-23 (2013).

21 Herawati, H., Hamdani, H., Hasan, Z. & Dewi, Q. C. Utilization of Aquatic Plants as Phytoremediation Agents of Tofu Liquid Waste. *Asian Journal of Fisheries and Aquatic Research*, 1-9 (2020). https://doi.org:10.9734/ajfar/2019/v5i330076

22 Das, D. *et al.* Aquatic Plants in phytoremediation of contaminated water: Recent knowledge and future prospects. *Journal of advanced zoology* (2023). https://doi.org:10.53555/jaz.v44iS6.3721

23 Bian, F., Zhang, X., Li, Q., Huang, Z. & Zhong, Z. Enhancement of phytoremediation of heavy metal pollution using an intercropping system in Moso Bamboo Forests: Characteristics of soil organic matter and bacterial communities. *Forests* **14** (2023). https://doi.org:10.3390/f14091895

24 Rahman, R. A., Wintoko, J. & Prasetya, A. Comparison of different phytoremediation strategies for acid mine drainage (AMD). *IOP Conf. Ser.: Earth Environ. Sci.* **963** (2022). https://doi.org:10.1088/1755-1315/963/1/012040

25 Hardestyariki, D. & Fitria, S. Potential of Neptunia oleracea L. as a Phytoremediation Agent for Petroleum Liquid Waste. *Journal of Ecological Engineering* **24**, 88-94 (2023). https://doi.org:10.12911/22998993/161296

26 Abu Bakar, A. F., Yusoff, I., Fatt, N. T., Othman, F. & Ashraf, M. A. Arsenic, zinc, and aluminium removal from gold mine wastewater effluents and accumulation by submerged aquatic plants (Cabomba piauhyensis, Egeria densa, and Hydrilla verticillata). *Biomed Res Int* **2013**, 890803 (2013). https://doi.org:10.1155/2013/890803

Author contributions

All authors contributed to this article. The conception and design, material preparation, data collection, and analysis were performed by **[Lilla Panca Faizsyahrani]**, **[Maria Ulfah]**, **[Sumarno],** and **[Muhammad Syaipul Hayat]**. The first draft of the manuscript was written by **[Lilla Panca Faizsyahrani]**. All authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.