Biological Environment and Pollution
Vol. 3(2) 2023 | 76 - 82
ISSN 2798-2378
ISSN 2798-2777

Water bamboo plant (*Equisetum hyemale*) as a phytoremediation agent for water pollution waste

Septiana Kurniawati [a, 1], Maria Ulfah [a, 2], Atip Nurwahyunani [a, 3], Muhammad Syaipul Hayat [b, 4, *]
[a] Department of Biology Education, Universitas PGRI Semarang, Jawa Tengah, Indonesia
[b] Magister of Natural Science Education, Universitas PGRI Semarang, Jawa Tengah, Indonesia
[1] sa6529526@gmail.com; [2] mariaulfah@upgris.ac.id; [3] atipnurwahyunan@upgris.ac.id;
[4] m.syaipulhayat@upgris.ac.id*
* Corresponding author

ARTICLE INFO

Article history
Submission
September 23, 2023
Revision
November 30, 2023
Accepted
December 23, 2023

Keywords
Equisetum hyemale
Phytoremediation
Water Bamboo
Water pollution

ABSTRACT

The aquatic bamboo plant (*Equisetum hyemale*) can be used as a phytoremediation agent because it has hyperaccumulator properties and is hyper-tolerant of pollutants. With the increasing number of industrial and household activities, managing waste before it is disposed of directly into the environment. This research aims to determine the application of phytoremediation in reducing pollutant content in water pollution waste. The research method was carried out using a literature research design review of the Google Scholar and SINTA databases starting from publication year 2014 to 2023 by reviewing a total of ten national journal articles. The research results show that phytoremediation can reduce wastewater pollution content, especially BOD and COD levels accumulated by the roots of aquatic bamboo plants. The effective time for the phytoremediation method is 3 days, 5 days, and 12 days which can reduce the number of contaminants in sample water according to wastewater quality standards. The novelty of this research is in the variables studied, namely BOD and COD levels using aquatic bamboo plants.

Conflict of interest: The authors declare no conflicts of interest.

Introduction

Water bamboo (*Equisetum hyemale*) is one of the aquatic plants that can be used as a phytoremediation agent. The high silicate concentration in water bamboo plant stems is useful for binding particles absorbed by plant roots. Water bamboo has strong and winding roots so it does not rot even if submerged in water [1,2]. The stems are green, segmented, contain silica, are hollow in the middle and branched, and function as substitutes for leaves as photosynthetic organs. Water bamboo leaves are not reproductive, they only resemble scales that cover the segments. The average height is 70 cm, and the stem diameter ranges from 0.4 to 0.6 cm.

Aquatic bamboo plants work well in wastewater treatment because they can absorb contaminants at different concentrations, including organic substances and dangerous compounds[1]. Water bamboo plants are hyperaccumulators and hypertolerant to contaminants so this plant can be used as a phytoremediation agent. These plants can concentrate heavy metals at very high biomass levels. According to research conducted by Widyastuti et al.[3] water bamboo is a hyperaccumulator plant that reduces levels of the heavy metal Zn in leachate. Water

bamboo is also a hyper-tolerant plant that can adapt to its environment and survive because of its high tolerance for contaminated environments.

The introduction of organisms, liquids, solids, energy, or other elements into water that degrade the water quality to the point that the water becomes unusable is known as water pollution. Water pollution can be caused by human activities, natural disasters, or both, which reduce water quality[4,5]. Water pollution can come from waste spread throughout homes, farms and plantations, as well as waste concentrated in places such as hotels, hospitals and industry which can pollute water supplies. Pollution limits for various types of water vary according to the needs of each living creature, so that if pollution occurs the water is unfit for use[6,7]. Aquatic life and human health can be negatively impacted by water pollution.

Based on this, appropriate countermeasures are needed to overcome the problem of water pollution to meet the quality standards set out in the 2014 and 2016 Minister of Environment and Forestry Regulations concerning wastewater quality standards. Phytoremediation is one method that can be attempted. Phytoremediation is a system where certain plants can change contaminants (pollutants) by working together with microorganisms in the media (soil, coral and water) so that they become less dangerous and even turn into materials with commercial value[8,9]. Certain plants are grown in liquid waste for processing, and these plants could absorb, collect, and break down certain contaminants present in the waste. Plant selection is an important step in phytoremediation research. To grow and survive in a contaminated environment, plants must have the capacity to absorb and accumulate pollutants efficiently[10,11]. This research aims to determine the application of phytoremediation by aquatic bamboo plants in reducing pollutant content in water pollution waste.

Method

This research method is literature review, namely a research method by specifically reviewing or summarizing empirical or theoretical literature. Results from the literature the review provides a more comprehensive understanding of the application of phytoremediation in reducing pollutant content in water pollution waste[12].

This research method aims to analyze and summarize available knowledge regarding the research subject. Automatic article search using Google Scholar and SINTA databases. To analyze a total of ten articles published in national journals, literature review starting from the publication year 2014 to 2023. To search for publications in Indonesian, the following keywords are used: water bamboo, phytoremediation, wastewater, and water pollution.

Results and Discussion

Literature findings review, a total of 10 articles were obtained. The results of the empirical study related to the article are presented in Table 1.

Table 1. Waste sample analysis results and research parameters

Author	Sample	Parameter
Widyastuti et al.[3]	Leachate	Heavy metal content (Zn)
Triastianti et al.[13]	Artificial waste	Lead (Pb)
Siswandari et al.[14]	Laundry liquid waste	Phosphate content and pH
Kencana & Radityaningrum[15]	Batik industry liquid waste	COD, BOD, Pb
Riyanto[1]	Tofu factory waste	BOD
Margowati & Abdullah[16]	Household waste	BOD, COD, pH, temperature
Pratiwi et al.[17]	Palm oil mill liquid waste	COD, pH, TSS, turbidity, N, K
Wulandari & Hartini[10]	Household liquid waste	Detergent level
Al Kholif et al.[18]	Household waste	BOD_5 and COD
Nugraha[19]	Tofu industry liquid waste	BOD_5

Based on Table 1, it can be seen that the waste water samples used in several journals are said to come from leachate[3], artificial waste[13], industrial waste[1,14,15,17,19], and household waste[10,16,18]. The aim of all journal article studies is to determine how well aquatic bamboo plants can remove contaminants in water pollution waste through phytoremediation.

Industrial waste comes from laundry[14,19], batik industry[15], tofu factory[1], and palm oil mills[17]. Industrial waste includes residue or waste resulting from industrial activities in the form of liquid, solid, gas, or other dangerous and toxic compounds which can harm aquatic biota if not treated first. Good industrial waste management is needed to reduce these bad impacts. Part of this waste treatment involves the use of phytoremediation methods, a process in which pollutants are broken down by plants into harmless substances before being disposed of.

Water bamboo is one of the aquatic plants that can be used as a phytoremediation agent. The high silicate content in water bamboo plant stems is useful for binding particles received by plant roots. Aquatic bamboo plants work well in wastewater treatment because they can absorb contaminants at different concentrations, including organic and dangerous compounds[1]. Water bamboo plants are hyperaccumulators and hypertolerant of contaminants, so this plant can be used as a phytoremediation agent. This plant can concentrate heavy metals at very high levels in its biomass. Widyastuti et al.'s research[3] used water bamboo as a hyperaccumulator plant to reduce levels of the heavy metal Zn in leachate water. Water bamboo is also a hyper-tolerant plant that is able to adapt to its environment and survive because of its high tolerance for contaminated environments. Water bamboo plants are able to absorb levels of Zn, Pb, P, N, COD (Chemical Oxygen Demand), BOD (Biological Oxygen Demand), and TSS (Total Suspended Solid) in waste water with the highest average uptake of contaminants being in the roots[3,10,16].

Based on these 7 journals, it is known that the batch system is used in the plant preparation method. Plants are planted using a batch system in wastewater media then sample testing is carried out at the end of treatment[20,21]. This method was carried out for 12 days by inserting water bamboo into a reactor that holds liquid waste with observations made every three days[3,10,19]. The water bamboo plants used were young plants that were two months old and fresh green in color[1,15]. However, other studies used water bamboo that was 3-4 months old[16]. Water bamboo plants are assembled into one clump consisting of 60 stems with close spacing between the stems[10].

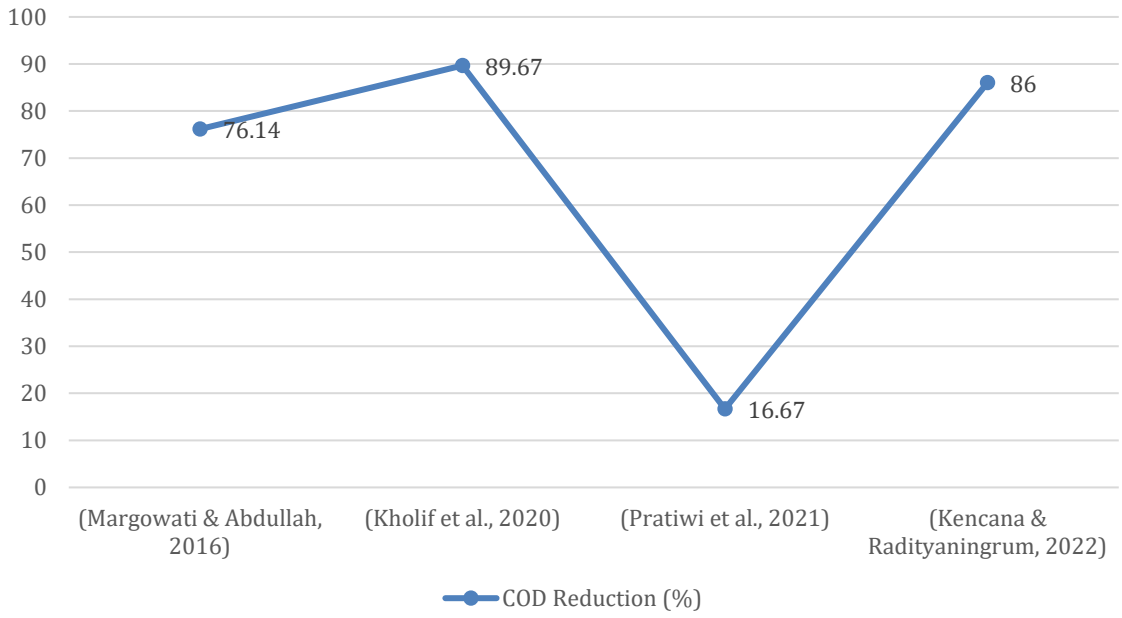

Fig 1. COD level reduction analysis

Fig 1 shows three journals which state that the use of water bamboo in phytoremediation has succeeded in reducing COD levels to the quality standards stipulated in the 2014 and 2016 Minister of Environment and Forestry Regulations concerning wastewater quality standards[15,16,18]. However, because the reduction results have not yet reached quality standards, the reduction results are less effective even though one study stated that phytoremediation was successful in reducing COD levels in wastewater samples[17].

The effectiveness of using aquatic bamboo plants to reduce COD levels in wastewater can be evaluated by comparing the COD content after phytoremediation treatment with quality standards. If there is only a decrease in COD levels but does not reach the quality standards, then the results of reducing COD levels are considered less effective. The results of research by Kencana and Radityaningrum[15] stated that the highest COD removal efficiency for 12 days was 86%. Margowati and Abdullah[16] in their research stated that COD levels decreased for 3 days based on variations in plant weight of 0 kg; 0.5kg; 0.75 kg sequentially at 76.35%; 76.14%; 73.69%. According to research by Al Kholif et al.[18] 89.67% of COD levels can be reduced after 5 days. According to the analysis results, phytoremediation is considered effective if the processing results meet the COD levels set by the 2014 and 2016 Minister of Environment and Forestry Regulations concerning waste water quality standards. Research published states that the use of phytoremediation methods is effective in reducing COD levels in wastewater[15,16,18].

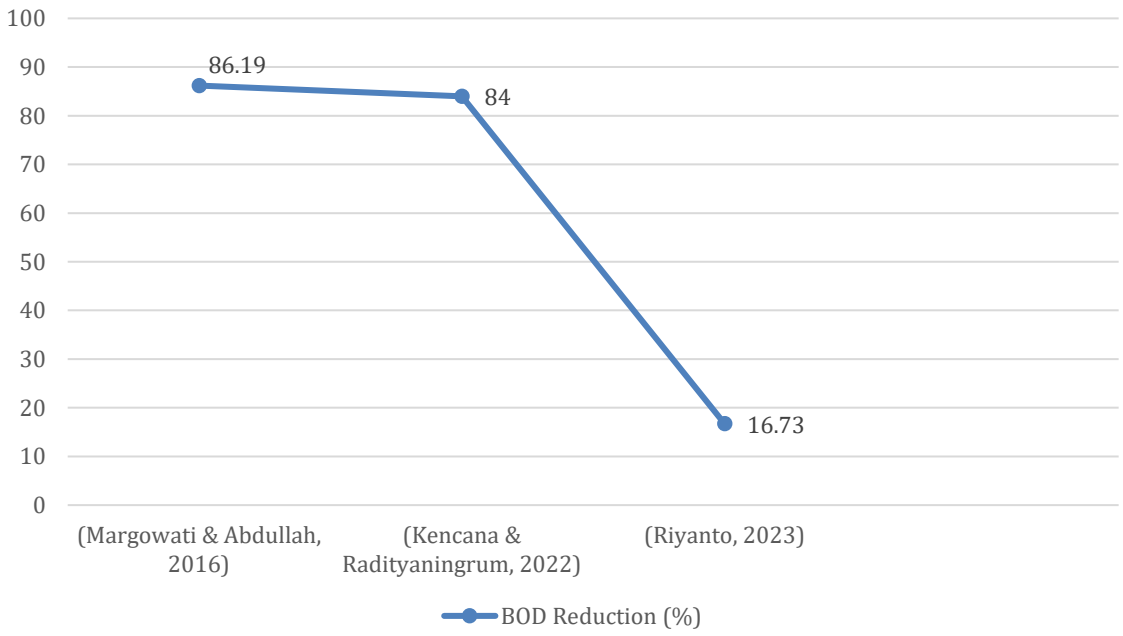

Fig 2. Results of analysis of reduction in BOD levels

Fig 2 shows two articles (Kencana & Radityaningrum[15]) and (Margowati & Abdullah[16]) states that BOD levels can be reduced effectively with phytoremediation using water bamboo until it reaches the quality standards set by the Minister of Environment and Forestry Regulations of 2014 and 2016. Meanwhile, one article states that although phytoremediation is successful in reducing BOD levels in samples wastewater, the reduction is less significant because it does not meet quality standards[1].

The results of research on BOD levels after phytoremediation treatment compared with quality standards show the success rate of reducing BOD levels in wastewater by using aquatic bamboo plants. If BOD levels only decrease but do not reach the specified quality standards, then the results of reducing BOD levels are considered less successful[22]. The highest effectiveness of BOD removal was recorded on the 12th day at 84% according to research data from Kencana and Radityaningrum[15]. Margowati and Abdullah[16] in their research revealed that

BOD levels decreased over 3 days when plant weight varied from 0 kg; 0.5kg; 0.75 kg the results are 26.88; 80.55; 86.19. Based on this analysis[15,16], phytoremediation is effective because the processing results meet the BOD quality standards set by the 2014 and 2016 Minister of Environment and Forestry Regulations concerning wastewater quality standards.

Three mechanisms are used by plants to break down pollutants, namely absorbing pollutants directly, accumulating non-phytotoxic metabolism in plant cells, releasing exudates and enzymes that can activate microbiological activity, and absorbing minerals in the root area. The amount of oxygen dissolved in wastewater increases because of plant photosynthesis. The process of phytodegradation and organic pollutants that enter the plant through the roots and decompose through metabolic processes in the plant can cause a decrease in COD and BOD levels[23,24]. A process known as phytovolatization can lead to a reduction in pollutants, where pollutants are absorbed by plants and then released into the atmosphere as water vapor. Solid materials have settled so that there is a decrease in the amount of waste material in wastewater which causes a reduction in BOD and COD concentrations[15,17,25,26]. Additionally, in order for plant roots to break down pollutants, some of the waste material has been oxidized and some has also been absorbed[27,28]. This decrease is also due to the sufficient supply of dissolved oxygen, especially from plant photosynthesis, causing the decomposition of organic matter to be more effective.

The availability of dissolved oxygen, especially from plant photosynthesis, which accelerates the decomposition of organic matter, is another factor that contributes to reducing pollutants. Based on the results of the analysis of ten journal articles, it shows that the accumulation of contaminants in aquatic bamboo plants causes a decrease in BOD and COD levels in wastewater. As a result, periods of 3 days, 5 days and 12 days can reduce BOD and COD levels in sample water. If phytoremediation can reduce BOD and COD levels according to the quality standards shown in Table 2, then phytoremediation is considered effective.

Table 2. Wastewater Quality Standards

Waste Samples	COD (mg/L)	BOD (mg/L)
Leachate	300	150
Laundry industry waste	180	75
Palm oil industry waste	350	100
Batik industry waste	150	60
Tofu industrial waste	300	150
Household waste	100	30

Source: Minister of Environment and Forestry Regulations 2014 and 2016

Phytoremediation method has several conveniences, one of which is using aquatic plants that are easy to cultivate. Therefore, for aquatic bamboo plants to reduce BOD and COD in wastewater as effectively as possible, monitoring their growth is necessary for successful use of the method phytoremediation.

Conclusion

The results of literature studies show that phytoremediation can reduce wastewater pollution content, especially BOD and COD levels accumulated by the roots of aquatic bamboo plants. The effective time for the phytoremediation method is 3 days, 5 days and 12 days which can reduce the amount of contaminants in sample water according to waste water quality standards. Based on the advantages and disadvantages of journal articles in this literature study, it is recommended that future researchers include complete research information, such as descriptions of research variables and discussion of the effectiveness of reducing pollutant content in the wastewater samples tested.

References

1 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

2 Kartini, A. M., Pramitasari, N. & Kholisah, A. N. Efisiensi penyisihan kadar BOD pada limbah cair tahu menggunakan tanaman bambu air dengan sistem sub surface flow constructed wetland. *Jurnal Envirotek* **14**, 66-73 (2022). https://doi.org:10.33005/envirotek.v14i1.188

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 Yohannes, B. Y., Utomo, S. W. & Agustina, H. Kajian kualitas air sungai dan upaya pengendalian pencemaran air. *IJEEM - Indonesian Journal of Environmental Education and Management* **4**, 136-155 (2019). https://doi.org:10.21009/ijeem.042.05

5 Istarani, F. & Pandebesie, E. S. Studi dampak Arsen (As) dan Kadmium (Cd) terhadap penurunan kualitas lingkungan. *Jurnal Teknik ITS* **3**, 53-58 (2014).

6 Shaleh, F. R., Mas'ud, F. & Permana, T. A. Kajian kualitas air sumur seabgai sumber air bersih di Kecamatan Babat Kabupaten Lamongan. *Grouper : Jurnal Ilmah Perikanan* **9**, 1-11 (2018).

7 Koniyo, Y. Analisis kualitas air pada lokasi budidaya ikan air tawar di Kecamatan Suwawa Tengah. *Jurnal Technopreneur (JTech)* **8**, 52-58 (2020). https://doi.org:10.30869/jtech.v8i1.527

8 Irmayani, I., Fetindah, S. P. & Komalasari, I. Phytoremediation based *Typha latifolia* landscape design strategy for lapindo mud land recovery and eco-tourism Sidoarjo. *Nabatia* **10**, 35-44 (2022). https://doi.org:10.21070/nabatia.v10i1.1606

9 Dewi, M. O. & Akbari, T. Pengolahan limbah cair tahu dengan metode fitoremediasi tanaman Enceng Gondok (Eichornia Crassipes) pada industri tahu B Kota Serang. *Jurnal Lingkungan dan Sumberdaya Alam* **3**, 38-48 (2020).

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

11 Nabila, S., Afifudin, A. F. M. & Irawanto, R. Pengaruh pencemaran Linear Alkylbenzene Sulfonate (LAS) dan tembaga (Cu) terhadap produksi klorofil pada tanaman daun tombak (*Sagittaria lancifolia*). *Spizaetus: Jurnal Biologi dan Pendidikan Biologi* **4** (2023). https://doi.org:10.55241/spibio.v4i2.162

12 Maurya, A., Sharma, D., Partap, M., Kumar, R. & Bhargava, B. Microbially-assisted phytoremediation toward air pollutants: Current trends and future directions. *Environmental Technology & Innovation* **31** (2023). https://doi.org:10.1016/j.eti.2023.103140

13 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).

14 Siswandari, A. M., Hindun, I. & Sukarsono, S. Fitoremediasi phospat limbah cair laundry menggunakan tanaman melati air (*Echinodorus paleafolius*) dan bambu air (*Equisetum hyemale*) sebagai sumber belajar biologi. *Jurnal Pendidikan Biologi Indonesia* **2**, 222-230 (2016).

15 Kencana, E. M. & Radityaningrum, A. Kombinasi filtrasi dan fitoremediasi untuk pengolahan limbah cair industri batik. . *Dampak: Jurnal Teknik Lingkungan*, 56-65 (2022). https://doi.org:10.25077/dampak.19.2.56-65.2022

16 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
17 Pratiwi, A., Subiantoro, R. & Delvitasari, F. The use of phytoremediaton with an up-flow system to reduce pollutants at anaerobic pond outlets II palm oil mill effluent (*Elaeis guineensis Jacq.*). *Agrosains : Jurnal Penelitian Agronomi* **23**, 89-98 (2021). https://doi.org:10.20961/agsjpa.v23i2.50101
18 Al Kholif, M., Hidayat, S., Sutrisno, J. & Suning, S. Pengaruh tanaman Bintang Air (*Cyperus Papyrus*) dan Bambu Air (*Equisetum Hyemale*) dalam mengolah limbah domestik. *Jurnal Serambi Engineering* **5** (2019). https://doi.org:10.32672/jse.v5i1.1596
19 Nugraha, A. S. & Iw, H. R. Efisiensi bambu air (*Equisetum hyemale*) sebagai fitoremediator kadar biological oxygen demand pada limbah cair industri tahu di Desa Prembun Kecamatan Tambak Kabupaten Banyumas tahun 2015. *Buletin Keslingmas* **34**, 189-194 (2015). https://doi.org:10.31983/keslingmas.v34i3.3071
20 Wahyudi, A. & Hendraningsih, L. *Biogas fermentasi limbah peternakan*. (UMM Press, 2020).
21 Rahman, D., Priambodo, E., Caturputranto, T. & Wahyudianto, F. Kinetics of pollutants removal in wetlands influenced by retention time and number of plants using Cyperus alternifolius. *Journal of Ecological Engineering* **23**, 37-43 (2022). https://doi.org:10.12911/22998993/154848
22 Adiningsih, R. & Ahmad, H. Efektivitas metode fitoremediasi menggunakan Tanaman Eceng Gondok dan Kangkung Air dalam menurunkan kadar BOD dan TSS pada limbah cair industri tahu. *Jurnal Farmasetis* **8**, 31-38 (2019). https://doi.org:10.32583/farmasetis.v8i2.599
23 Kasman, M., Riyanti, A. & Kartikawati, C. E. Fitoremediasi logam Aluminium (Al) pada lumpur instalasi pengolahan air menggunakan Tanaman Melati Air (*Echinodorus palaefolius*). *Jurnal Daur Lingkungan* **2** (2019). https://doi.org:10.33087/daurling.v2i1.17
24 Pramesti, T. A. & Mirwan, M. Penurunan TSS, COD, dan total Nitrogen air lindi dengan constructed wetland menggunakan Melati air (*Echinodorus palaefolius*). *Jurnal Pengendalian Pencemaran Lingkungan (JPPL)* **5**, 189-195 (2023). https://doi.org:10.35970/jppl.v5i2.2010
25 Ain, S. Z. & Noviana, L. Efektivitas Melati Air dalam menurunkan kadar BOD, COD dan TSS pada air limbah laundry. *Sustainable Environmental and Optimizing Industry Journal* **1** (2021). https://doi.org:10.36441/seoi.v1i2.174
26 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).
27 Kustiyaningsih, E. & Irawanto, R. Pengukuran Total Dissolved Solid (TDS) dalam fitoremediasi deterjen dengan tumbuhan *Sagittaria lancifolia*. *Jurnal Tanah dan Sumberdaya Lahan* **7**, 143-148 (2020). https://doi.org:10.21776/ub.jtsl.2020.007.1.18
28 Musapana, S., Dewi, E. R. S. & Rahayu, R. C. Efektivitas Semanggi air (*Marsilea crenata*) terhadap kadar TSS pada fitoremediasi limbah cair tahu. *Florea : Jurnal Biologi dan Pembelajarannya* **7** (2020). https://doi.org:10.25273/florea.v7i2.7645

Author contributions

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