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Analysis of the characteristics of batik wastewater and phytoremediation of water spinach on lead concentration at SMK 4 Pekanbaru

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Abstract

Background: SMK 4 Pekanbaru is the only vocational school that focuses on batik production as a field of expertise to preserve the traditional batik of Riau. The batik production process generates wastewater at this school, which is discharged directly into the drainage system without any treatment. Wastewater, whicih is generally not well managed, has the potential to pollute the surrounding environment, particularly soil and water. This study aims to assess the characteristic of the wastewater and the effectiveness of phytoremediation using water spinach in reducing lead concentrations in batik wastewater.
Method: this research is a laboratory experimental study that analyzes the charactistics of batik wastewater produced and tests the effectiveness of phytoremediation using water spinach to reduce lead content in batik wastewater, using a pretest-posttest controlled group design. Data were analyzed using frequency and descriptive test and paired sample test.
Results: The analysis of the characteristics of the wastewater shows that several parameters exceed the threshold values, namely pH, BOD5, COD, and chromium. The phytoremediation test using water spinach (Ipomoea aquatica) was able to reduce the lead (Pb) content in batik wastewater over 89.5%. The results of paired samples test provide strong evidence that water spinach effectively reduces lead concentration
Conclusion: Phytoremediation process using water spinach is eco-friendly, cost-effective and promising method for mitigating lead contamination in batik wastewater. To optimize the effectiveness of phytoremediation, future efforts should focus on balancing the duration of treatment with the health of the plants to maintain their remediation potential.

Keywords: Phytoremediation; Water Spinach; Lead; Batik; Wastewater

INTRODUCTION

Riau Batik initially used a unique stamping process without wax, differing form Javanese methods. Since 1985, traditional methods involving canting and wax have been reintroduced in Riau. The batik industry in Indonesia includes large-scale, medium and household production, focusing on pattern and quality preservation (1)(2)(3).

Batik production generates liquid waste containing phenols, sulfides, and heavey metals like Pb, Cr, Zn, Cu and Cd. This waste is dense, viscous and potentially harmful to the environment, especially water bodies (1).

The batik production process generates liquid waste that poses significant environmental risk due to its complex chemical composition. This waste is often inadequately managed, leading to potential contamination of soil and water bodies (4)(5). The waste is characterized by its density, viscosity, unpleasant odor, turbidity, and high pH, containing harmful substances such as phenols, sulfides, and heavy metal like lead, chromium, zinc, copper and cadmium, which are challenging for aquatic microorganisms to decompose. Various treatment methods have been explored to mitigate these environmental impacts (6).

Phytoremediation using plants like water spinach can effectively reduce pollutants in wastewater, water spinach has shown effectiveness in reducing ammonia an COD levels in various wastewaters (7).

While traditional batik methods and natural dyes are being revisited for their envionemntal benefits, the challenge remains in balancing cultural preservation with modern environmental concerness(5). The use of natural dyes, which are more environmentally friendly, is gaining renewed interest, offering a potential solution to the environmental issues associated with synthetic dyes (5).

SMK 4 Pekanbaru is the only vocational high scholl in region that offers a specialized program in Riau batik making, highlighting its unique position in educational landscape. The school plays a crtucial role in preserving and promoting the unique cultural heritage of Riau batik by equipping students with the necessary skills to meet industry demands. It's focus on batik making aligns with broader educational and industrial strategis aimed at enhancing vocational training and aligning it with modern challenges.

Lead (Pb) exposure, even at low levels, poses significant health risks, particularly to children and adults. Lead exposure in children can cause neurodevelopmental and neurobehavioral issues, including impaired learning and memory abilities due to disrupted neural circuits in the brain. Lead can cross the blood-brain barrier, affecting the central nervous system and altering synaptic connections and neuronal migration. In adults, lead exposure is linked to cardiovascular issues, such as increased blood pressure and nephrotoxicity (8)

Aquatic plants play a crucial role in sewage treatment due to their ability to adsorb nutrients and support microbial communities that filter contaminants. The most effective plants for this purpose include Scirpus californicus, Zizaniopsis miliaceae, Panicum Helitomom, Pontederia cordata, Sagittaria lancifolia, Ipomea sp, and Typha latifolia. These plants are particularly benefical because they grow rapidly and can directly uptake nutrients form the water, while their roots provide a habitat for microbes that help in filtering and absorbing suspended particles, thus removing nutrients form the water column (9)(10).

Sagittaria lancifolia and Ipomea sp, their rapid growth and nutrient uptake form the water column make them suitable for sewage treatment applications (11). Floating plant species, are advantageous due to their ability to absorb nutrients directly form water, which is crucial for efficient sewage treatment. The roots of these plants foster microbial growth, which aids in the filtration and absorption of suspended particles, enhancing the overall nutrient removal form the water column (10)(12).

The water spinach variety, is known for its ability to absorb heavy metals form its environment. Water kale, or Ipomoea aquatica, is an aquatic plant that thrives in nutrient-poor water, often found inresidential wastewater channels. It is characterized by larger stems and leaves, reddish-white flowers, green stems, and pale seed pods, distinguishing it from land kale (13).

In urban environments, kale has been found to contain heavy metals such as cadmium and mercury at levels exceeding permissible limits, although lead and iron levels remain within safe boundaries. The highlights the plant's capacity to absorb and accumulate various heavy metals from its growing medium (14).

Phytoremediation using water spinach significantly reduced ammonia levels in hospital wastewater by 98,67% (Alya &

Haryanto, 2022). Other studies have shown water spinach reduced COD levels in tofu wastewater by 80-88% (7).

The preliminary survey indicates that the batik vocational field at SMK 4 Pekanbaru has not implemented any treatment for the liquid waste generated during the batik-making process. This untreated waste is directly discharged into sewer, potentially leading to environmental pollution and aesthetic degradation in nearby residential areas. Effective wastewater treatment procedures are necessary to mitigate these risks.

Lead contamination in batik wastewater is a niche area. Most studies focus on more common industrial effluents (e.g., textile or mining industries), but batik wastewater is unique due to the dyeing process involved, which often results in wastewater with different properties.

The specific interaction between water spinach (Ipomoea aquatica) and lead (Pb) in batik wastewater has not been comprehensively explored. While there is literature on water spinach's ability to absorb heavy metals form water, your research focuses on an underexplored source of contamination-batik wastewater.

This research is specific to SMK 4 Pekanbaru in Riau, relevant to local environmental issues and contributes to addressing regional wastewater management concerns. It is focusing on selecting water spinach plants due to their potential benefits, such as their ability to thrive on river surfaces or wetlands and their resilience in polluted wastewater environments. This makes them ideal candidates for phytoremediation, a process that uses plants to clean up environmental contaminants. Additionally, the variability in batik waste characteristics necessitates a thorough analysis to enhance the effectiveness of waste management strategies. The following sections delve into specifics of these aspects.

Therefore, the intention of this article is to provide the characteristics of batik liquid waste produced by SMK 4 Pekanbaru and the effectiveness of water spinach phytoremediation against lead levels in this waste can be understoods through the analysis of similar studies.

METHOD

The study utilized a controlled group design, a standars approach in experimental research to evaluate treatment effects by comparing outcomes between a treatment group and a control group. The difference in outcomes between the experimental and control groups is analyzed to determine the treatments's impact.

The study in question employed design with a controlled group set-up, where one group received the treatment (experimental group) and the other did not (control group). The primary aim was to identifiy the difference in outcomes between these two groups, attributing any observed differences to the treatment effect. This approach is a common method in experimental research to assess the efficacy of interventions by comparing the treatment group against a baseline or control group. The following sections elaborate on the key aspects of this design.

The research was conducted over a period of six weeks, form January to February 2024, at the Environmental Health Laboratory of Riau Province and the Chemistry Laboratory of Riau University. The timeline included sample collection, plant acclimatization, experimental setup, data collection and laboratory analysis.

The sampling process described involves collecting wastewater form a batik waste disposal container at SMK 4 Pekanbaru. A total of 40 liters of wastewater is collected, with 10 liters allocates to three experimental reactors and another 10 liters for a control tub. The sampling occurs over a span of 6 days, with samples taken at 2-days intervals. Additionally, 400 grams of water kale, acclimatized for one week, is used in the experiment. This set-up is designed to study the effects of batik wastewater on plant growth and potentially assess the wastewater's quality and treatment efficacy.

Data Collection Procedure

The data collection procedure involves assessing lead (Pb) levels in water through laboratory tests using biomarker specimens from liquid waste, measured in g/dl. This process evaluates the effectiveness of water spinach (Ipomea aquatica) as a phytoremediation agent to reduce lead levels. The procedure include measuring lead concentrations in liquid waste before and after treatment with water spinach to determine the extent of reduction.

Waste measurement procedure

The waste measurement procedure involves tow main stages : pre-treatment and post-treatment analysis of wastewater, specifically focusing on the measurement of elemental lead (Pb) levels. Initially, wastewater is collected and measured before it undergoes treatment, whicih involves phytoremediation using water spinach plants. This phase establishes a baseline for lead content. Subsequently, the posttest phase involves measuring the lead levels after wastewater has effectiveness. This structured approach ensures a comprehensive evaluation of the phytoremediation process.

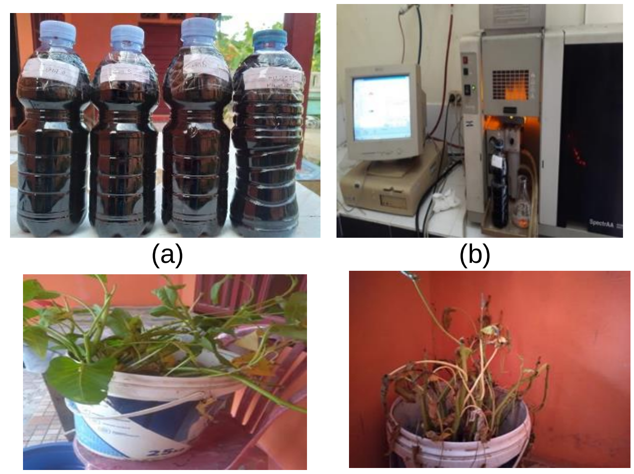
The analysis of data regarding the levels of lead in batik liquid waste was conducted using freaquency and descriptive

RESULTS

Univariate Analysis

Univariate analysis is conducted on a single variable from the research results to explain or describe the characteristics of each research variable. Generally, this analysis only results in the distribution and percentage of each variable studied.

Figure 1
Image of the results preparation



(a) (b)

(c) (d)

(a) the results of batik wastewater after phytoremediation process
(b) the testing process of Lead (Pb) using an Atomic Absorption Spectroscopy (AAS)
(c) the soaking process of water spinach in Batik Wastewater on the first day
(d) the soaking process of water spinach in Batik Wastewater on the sixth day

The research results, which compared the samples with treatment and without treatment, show a significant difference, as can be seen in the graph below :

Table 1
Batik Wastewater Characteristics Analysis at SMK 4 Pekanbaru

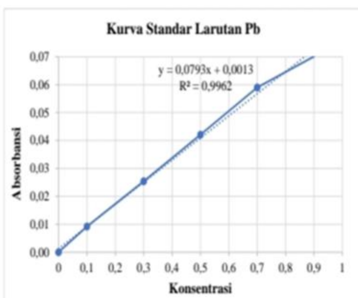
No	Parameter	Test Results
A	**Physics**	
1	TSS	119.5 mg/L
2	Color	2990 TCU
B	**Chemistry**	
1	pH	11.5
2	COD	815 mg/L
3	BOD5	530 mg/L
4	Total Chromium	0.018mg/L
5	Pb (Lead)	0.296 ppm

The test for the characteristics of batik wastewater produced at SMK 4 Pekanbaru show that the batik wastewater contains TSS levels of 11.95 mg/L, color of 2990 TCU, pH of 11.5, COD of 815 mg/L, Chromium of 0.018 mg/L, and Pb (lead) of 0.291 ppm.

The quality standards for batik wastewater in Pekanbaru City have not been clearly regulated in written rules as in other Province such as in Yogyakarta Special Region. Therefore, the determination of standars parameters refers to the wastewater threshold value for the textile industry (KepmenLH No.51/MENLH/10/1995). It is known that the pH of batik wastewater exceeds the threshold value, which is 6-9, COD exceeds the threshold value of 250 mg/L, and BOD5 exceeds the threshold value of 85 mg/L.

Graphics 1
Phytoremediation Results of water spinach on Lead Levels in Batik Wastewater at SKM 4 Pekanbaru

Larutan Standar	Absorbansi
0	0,0000
0,1	0,0092
0,3	0,0254
0,5	0,0421
0,7	0,0590
0,9	0,0701



Kode Sampel	Absorbansi	Konsentrasi (ppm)
Awal	0,025	0,296
2 hari	0,015	0,173
4 hari	0,008	0,082
6 Hari	0,004	0,031

The laboratory results show that the initial sample (without treatment of water spinach) had 0,296 ppm. Meanwhile, the sample treated with water spinach for 2 days had 0.173 ppm. Next, the sample treated with water spinach for 4 days had 0,82 ppm, and finally, the sample threated for 6 days had 0.031 ppm. This means that the longer the sample is treated with water spinach, the lower the lead content in the batik wastewater (sample). This indicate that water spinach can reduce the concentration of lead in batik wastewater.

Bivariate analyze was conducted to determine the ability to differentiate the concetration of lead content in batik wastewater over the 6-day measurement period. The results are considered effective if the P*value* is < 0.05, as shown in the table below:

Table 2 Paired Sample Test Results

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	0 hari (Sebelum Perlakuan) - 6 Hari (Sesudah Perlakuan)	.200667	.071933	.041530	.021976	.379358	4.832	2	.040

This test compares the lead concentration before and after phytoremediation to determine if the observed difference is statistically significant. It shows the Pvalue is 0.040, which is less than 0.05 that indicates the observed difference between the lead concentrations before and after treatment is statistically significant. This means the phytoremediation process using water spinach effectively reduced lead levels in the wastewater.

DISCUSSION

The results of this experiment show a reduction in lead levels in batik wastewater. The initial test, before planting water spinach had a lead concentration of 2,91 ppm. After 2 days of treatment, the concentration was reduced to 0.102 ppm, a decrease of 22%. After 4 days, the concentration decreased further to 0.076 ppm, a reduction of 42%, and after 6 days, the concentration was 0.053 ppm, a reduction of 59,6%. Media saturation leads to wilting and plant death, followed by decay. During the experiment, a decrease in the lead concentration in batik wastewater was observed, with the water spinach plant's weight dropping form 800 grams to 400 grams on the sixth day. Wilting and death were found in several water spinach plants used daily. This was marked by a yellowish-brown color change on the leaves and roots.

This is consistent with the research (15), which also explains that the acclimatization process causes water spinach to undergo changes due to being placed in clean water media for several days, leading to nutrient deficiencies for metabolism, which reduces plant functions. Furthermore, it is explained that after acclimatization, the plants were moved to containers filled with batik wastewater without mixing it with clean water, forcing the plants to adapt quickly. The plants then absorbed chemicals in the wastewater excessively. This excessive absorption led to physical changes in the plants.

This research aligns with (16) study on the use of water spinach (Ipomoea aquatica) to reduce ammonia, nitrite and nitrate concentrations in industrial wastewater. However, demonstrating the plant's effectiveness in phytoremediation processes by absorbing and metabolizing harmful compounds, thus improving water quality and contributing to sustainable wastewater management practises.

The use of phytoremediation to remove heavy metals from contamined water has gained significant attention due to its cost-effectiveness and sustainability compared to conventional methods (17) Among various plants tested for heavy metals removal, water spinach (Ipomoea aquatica) has shown remarkable potential due to its ability to absorb and accumulate metals like lead (Pb) from contaminated water (16). Lead contamination, a common issue in industries such as batik production, poses severe environmental and health risks, particulary in developing regions like southest asia (1).

In this study we assessed the effectiveness of water spinach in reducing lead concentration in batik wastewater overtime. The results demonstrate that the water spinach is highly effective in removing lead from batik wastewater, with a reduction of lead form 0.296 ppm in untreated samples to 0.031 ppm after six days of treatment.

This supports previous research, (17), which demonstrated the potential of water spinach to reduce heavy metal concentration in water. The gradual reduction in lead leveles over six-day period aligns with findings (18), who reported that the uptake of heavy metals in water spinach increases with prolonged exposure, enhancing its remediation capabilities. The time-dependent reduction in lead concentrations observed in our study highlights the importance of exposure duration in optimizing phytoremediation processes, a finding also supported by (19) who observed significant improvements in metal removal after extended treatment periods.

However, while the phytoremediation process was effective, it also revealed critical insights into the phytotoxicity of leads on the plants. As the duration of exposure increased, the plants began to show signs of wilt and death, particularly after six days of exposure. This aligns with the research (20), which highlighted that prolonged exposure to heavy metals like lead can result in severe damage to the plant's metabolic processes, leading to reduced growth and survival. The reduction in plant biomass observed in this study is consistent with the results (11), who also found that excessive metal accumulation caused physiological stress in water spinach, affecting its overall health. This underscores the need for balance in phytoremediation studies, where both the efficiency of heavy metal removal and plant health should be carefully monitored to optimize the process.

The findings of this study also contribute to a broader body of literature on the local applicability of phytoremediation in SMK 4 Pekanbaru and Riau province. As batik production is a significant industry in countries like Indonesia, where heavy metal contamination is growing concern, this research provides valuable insights into how local agricultural plants can be used in environmentally sustainable solutions. While many previous studies have focused on more conventional industrial effluents, such as those from mining or textile industries (16)(21). This study highlights the importance of investigating local pollutans and potential phytoremediation strategies tailored to the specific needs of the region. As batik wastewater present uniqie chacarteristics due to dyeing process and the presence of various chemicals, this study fills an important gap by providing an effective, cost-efficient method to address environmental challenges specific to batik wastewater.

Moreover, this research lies not only in the application of water spinach to batik wastewater, but also in the time-based analysis of its efficacy. Previous studies primarily focused on the immediate or short-terms effect of phytoremediation. But our research demosntrates how prolonged exposure periods can enhance remediation efficency. This findings are consistent with those (20), who suggested that exposure duration is a key factor influencing the effectiveness of phytoremediation. However, our study adds new knowledge by showing how plant health deteriorates as metal concentrations increase, which has important implications for optimizing treatment duration in real-world applications.

This research is limited to batik wastewater produced at SMK 4 Pekanbaru, short duration of observation, plant health decline, limited focus on lead (Pb) remediation and conducted on a laboratory scale which may not fully replicate the complexities and challenge of apllying phytoremediation larger scale.

CONCLUTION

In conclution, this study highlights the potential of water spinach (Ipomoea aquatica) as an effective phytoremediation agent for reducing lead (Pb) concentration in batik wastewater, specially from SMK 4 Pekanbaru. Through a six-day treatment preiod, lead levels were significantly reduced from 0.296 ppm to 0.031 ppm, demonstrating a reduction efficiency of 89.5%. this results emphasize the capability of water spinach to absorb and accumulate heavey metals, making it promising, sustainable solution for managing indutrial wastewater. This study also reveals important indication regarding the impact of prolonged exposure to heavy metals on plants health. This finding underscores the need to balance phtoremediation efficiency with strategies to maintain plant health during the treatment processes. Future research should explore ways to mitigate phytotoxicity, optimeize exposure durations, and assess the scalability of this technique for larger wastewater treatment system. By adressing these aspects, phytoremediation using water spinach can be further refined to enhance its practically and effectiveness in diverse industrial contexts.

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