Study on the Use of Citosan from Maps on the Reduction of Timbal (PB) Weight Metal Levels in Batik Waste

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ABSTRACTS

Background – The batik industry, both household and factory scale, is known to contribute heavy metal pollution to the environment. One of them is lead (Pb), which can interfere with various body systems such as the nervous system, reproductive system, as well as the growth and development of children. Treating waste before disposal into the environment is expected to reduce its adverse effects, adsorption is one method that is known to be quite effective.

Objective – This study aims to test the effectiveness of chitosan extracted from shrimp shells as an adsorbent for heavy metal lead (Pb) in batik dyeing waste.

Method – This research uses laboratory experimental method in several stages. Extraction of chitosan from shrimp shell through demineralisation, deproteination, depigmentation and deacetylation stages. Characterisation of chitosan was carried out using Fourier Transform Infrared Spectroscopy (FTIR) until the degree of deacetylation was ≥ 90%. Testing the ability to absorb lead (Pb) was carried out at concentrations: A (0.10%), B (0.25%) and C (0.5%).

Result – The results of analysis using Atomic Adsorption Spectrophotometry (AAS) showed a decrease in heavy metal lead (Pb) levels in the waste. The highest uptake capacity of 95.69% and the highest adsorption capacity of 10.3678 mg/L were found at a chitosan concentration of 0.50% with an interaction time of 30 minutes.

Managerial Implication – Chitosan from shrimp shells is an effective adsorbent for Pb in batik waste, which is expected to reduce its negative impact on the environment. This method can be a sustainable and environmentally friendly solution to the waste problem in the batik industry.

Keywords: Chitosan, Lead (Pb), adsorbing capacity, Atomic Adsorption Spectrophotometry

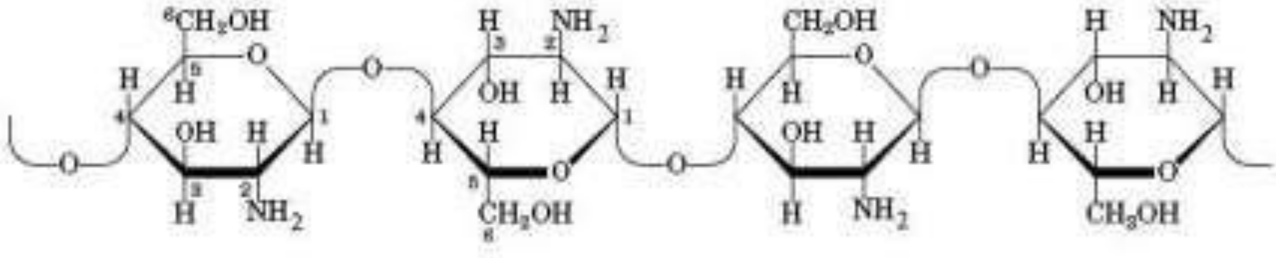
INTRODUCTION

The batik industry has long been a cultural icon deeply embedded in Indonesia's national identity. Rich in aesthetic and philosophical values, batik motifs not only reflect the beauty of traditional art, but also depict ancestral heritage that continues to live on in the modern era (Blaga, Zaharia & Suteu, 2021). The batik industry contributes significantly to the economy, creates jobs for millions of people, and strengthens Indonesia's image in the eyes of the world. But there is a major challenge that needs to be faced, namely the negative impact of its dyeing waste on the environment (Juliani, Rahmawati & Yoneda, 2021; Surana et al, 2024). The process of making batik often involves the use of chemicals that can pollute the environment. One of the most concerning heavy metal pollutants found in batik waste is lead (Pb) (Elamri, Zdiri, Hamdaoui & Harzallah, 2023). Lead is known to be very dangerous, both for the environment and human health, because it can damage various vital body systems such as the nervous system, reproductive system and cause developmental disorders in children. Given its serious impact, a more sustainable solution is needed to address this problem. The search for effective and environmentally friendly technologies to reduce lead levels in batik waste is becoming increasingly urgent, not only to protect the environment but also to maintain the sustainability of the batik industry itself (Francis et al, 2023; Ugraskan, Toraman & Yoruç, 2018).

The treatment of batik effluents has been the focus of much attention, given the negative impact it has on the environment, especially from heavy metals such as lead (Pb). While there have been various methods applied, such as the use of chemicals and filtration, many of them are still unable to effectively remove lead from the effluent (Manichandrika & Prathyusha, 2021). These methods often require large investments, both in terms of operational costs and infrastructure, making them less suitable for the small and medium-sized industries that dominate the batik sector. Not only that, some existing treatment techniques can also lead to new environmental impacts, such as secondary waste production or high energy utilisation, which ultimately just move the problem from one place to another (Riedel & Brigham, 2019; Debroy, Joshi, Yadav & George, 2023).

In this context, there is an urgent need to find alternative solutions that are more efficient, economical and sustainable. One promising innovation is the utilisation of chitosan, a natural polymer extracted from shrimp shells. Chitosan has the unique ability to bind heavy metals, including lead, thus providing a more environmentally friendly solution in batik waste treatment (Azzeddine et al, 2024). Besides being derived from abundant and readily available materials, the use of chitosan also supports the principle of circular economy by processing fishery industry waste into value-added products (Tripathi, Choppala & Singh, 2017). With this potential, chitosan not only offers a technical solution, but also opens up new opportunities for the development of technologies that support the sustainability of the batik industry in Indonesia (Ponomareva, Timchenko, Filippov, Lapaev & Sogorin, 2021). Although chitosan is known to have the ability to absorb heavy metals, not many studies have specifically examined its effectiveness in reducing lead levels in batik waste. Can chitosan really be used as an effective solution and can this process be widely applied on an industrial scale? These questions need to be answered so that the utilisation of chitosan can be a real solution in overcoming environmental problems due to batik waste (Muiz, Juwono & Krisnandi, 2022).

This research aims to examine the utilisation of chitosan from shrimp shells in reducing lead levels in batik waste. This research will be conducted through a series of experiments involving testing the effectiveness of chitosan under various conditions, including variations in concentration and contact time. The results of this study will be analysed to determine the extent to which chitosan can reduce lead levels, as well as its potential application on an industrial scale, so that it is expected to make a significant contribution to the development of environmentally friendly batik waste treatment technology. In addition, the utilisation of chitosan from shrimp shells can also be an economic solution that supports the principle of sustainability, while reducing fishery waste. The results of this study are also expected to be the basis for further research and the application of this technology in the batik industry at large. In an effort to find solutions to reduce the concentration of metal ions in wastewater effluents, adsorption methods are the main focus of this research. Adsorption, using materials such as chitosan that effectively bind heavy metal ion cations, provides a simple and economical solution (Gokarneshan, Padma & Rekha, 2021). Figure 1 shows the structure of chitosan produced from chitin compounds that can be isolated from shrimp shells, illustrating the potential of such natural materials as environmentally friendly adsorption materials.



Several methods have been developed to reduce the concentration of metal ions. Metal ion concentration in wastewater includes precipitation, ion exchange using resins, filtration and adsorption. Adsorption is the most commonly used method because it has a simpler concept and is also economical. Adsorption methods are generally based on the interaction of metals with functional groups present on the adsorbent surface through complex formation, and usually occur on the surface of solids rich in functional groups, such as: –OH, -NH, -SH and COOH. This research not only tries to answer concrete problems related to heavy metal pollution from the batik industry, but also positively contributes to the achievement of several SDGs targets, encouraging sustainable environmental management and human welfare.

MATERIALS AND METHODS

Research Design

This study uses a laboratory experimental method to test the effectiveness of chitosan extracted from shrimp shells in reducing lead (Pb) levels in batik waste (Manichandrika & Prathyusha, 2021). This research will be conducted in several stages, starting from chitosan extraction, chitosan characterisation, to testing the ability of chitosan to absorb Pb.

Materials and Tools

- **Materials:** Batik liquid waste containing lead (Pb), fresh shrimp shells, NaOH solution, acetic acid, HCl, standard Pb solution, and distilled water.
- **Tools:** Atomic absorption spectrophotometer (AAS), analytical balance, hot plate stirrer, oven, beaker glass, pipettes, and other basic laboratory equipment.

RESEARCH PROCEDURES

a. Extraction of Chitosan from Shrimp Shells

1. **Preparation of Shrimp Shells:** Shrimp shells were washed thoroughly with water to remove impurities, then dried and ground to a fine powder.
2. **Demineralisation:** Shrimp shell powder was soaked in 1N HCl solution for 24 hours to remove minerals, especially calcium carbonate. Afterwards, the residue was washed with water until neutral and dried.
3. **Deproteination:** The demineralised powder was soaked in 4% NaOH solution at 60°C for 24 hours to remove protein. The residue was washed again with water until neutral and
4. **Deacetylation:** This process is carried out by soaking the deproteinated powder in 50% NaOH solution at 120°C for 2-3 hours to convert chitin into chitosan. Afterwards, the residue was washed with water until neutral and dried.

b. Characterisation of Chitosan

1. **FTIR (Fourier Transform Infrared Spectroscopy) testing**: To identify the functional groups present in the extracted chitosan.
2. **Testing the degree of deacetylation**: To measure the degree of conversion of chitin to

c. Lead Adsorption Test by Chitosan

1. **Preparation of Lead (Pb) Solution**: A batik effluent solution with a certain level of Pb will be prepared as a test medium.
2. **Adsorption Testing**: The characterised chitosan is mixed with batik waste solution containing Pb. Variations in chitosan concentration and contact time will be tested to determine the optimal conditions for adsorption.
3. **Lead Level Analysis**: After the adsorption process, the solution was tested using an atomic absorption spectrophotometer (AAS) to measure the remaining Pb levels in the solution.

d. Data Analysis

The results of lead level measurements will be analysed to determine the effectiveness of chitosan in reducing Pb levels. The data obtained will be compared with the control condition (without chitosan) to determine the level of Pb reduction. Statistical tests such as ANOVA can be used to see the significance of differences between various experimental conditions.

Research Time and Location

This research will be conducted for 6 months in an environmental chemistry laboratory at an institution or university that has adequate facilities for chitosan extraction and heavy metal content testing.

Validation and Replication

To ensure the accuracy of the results, each test will be performed in triplicate. Test results will be compared with relevant literature for method validation.

Data Processing and Presentation

The data obtained will be presented in tables and graphs to facilitate interpretation of the results. The results will be discussed in the context of chitosan application as an environmentally friendly waste treatment material, as well as its potential implementation on a batik industry scale.

RESULT

Degree of Deacetylation

Knorr, (2004) stated, the degree of deacetylation is a parameter that determines the quality of chitosan, where this value shows the percentage of acetyl groups that can be removed from chitin. The higher the degree of deacetylation of chitosan, the lower the acetyl group of chitosan so that the interaction between ions with hydrogen bonds is stronger. The deacetylation degree of chitosan quality is industrial grade (DD $\geq$ 70%), food grade (DD $\geq$ 85%) and pharmaceutical grade (DD $\geq$ 90%) (Poeloengasih et al. 2008). In addition, BM also affects solubility, the smaller it is, the faster it dissolves (Du and Vuong 2019). The BM size of chitosan varies between 200-1000 kDa (Lodhi et al. 2014). The chitosan we use here is pharmaceutical grade which has a degree of distillation $\geq$ 90%. According to Suhardi, (1993), chitosan has met the standard as an adsorbent if the degree of deacetylation is greater than 60%. Thus, it can be said that the chitosan produced in this study meets the requirements as an adsorbent.

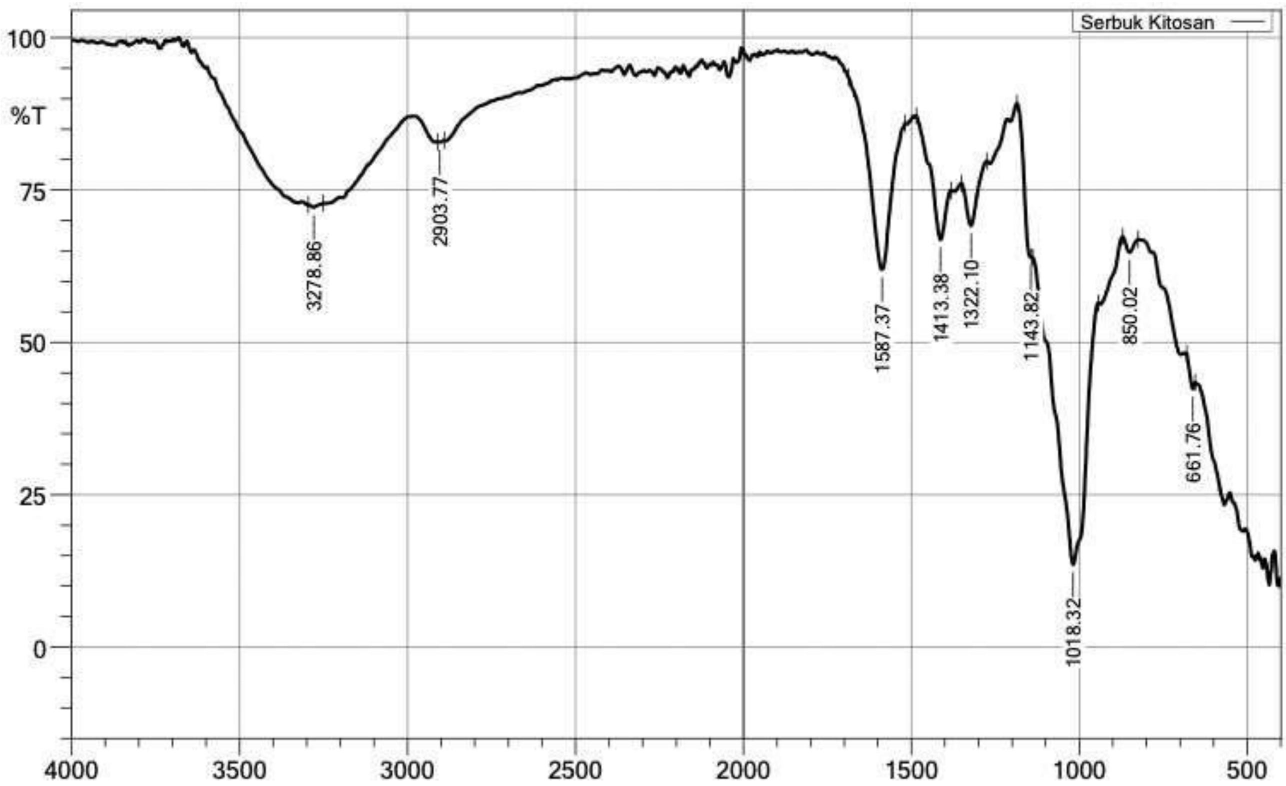


Figure 1: Results of FTIR Spectra of Chitosan Research

Chitosan Waste Adsorption Metal

Absorbance Data of Pb Waste Solution

(Waste) (The results of the application of heavy metal Pb (waste) with chitosan with concentration variations of 0.10%, 0.25% and 0.50% were obtained.

Table 1. Absorbance Data of Pb Waste Solution

Concentration	Absorbance
0	0,0000
2	0,0346
4	0,0864
6	0,1342
8	0,1666
10	0,2042
15	0,2858

According to the results of the above study, the highest Pb weight occurred at a concentration of 0.5%. According to Sahnaz Behnam (2015), at the beginning of adsorption, chitosan amino groups on the surface play an important role in the absorption of heavy metal Pb. The absorbency of chitosan to heavy metals decreases when the amino groups of chitosan on the surface are filled with Pb metal. Interaction in the Pb heavy metal adsorption process. The longer the interaction time, the more Pb is absorbed.

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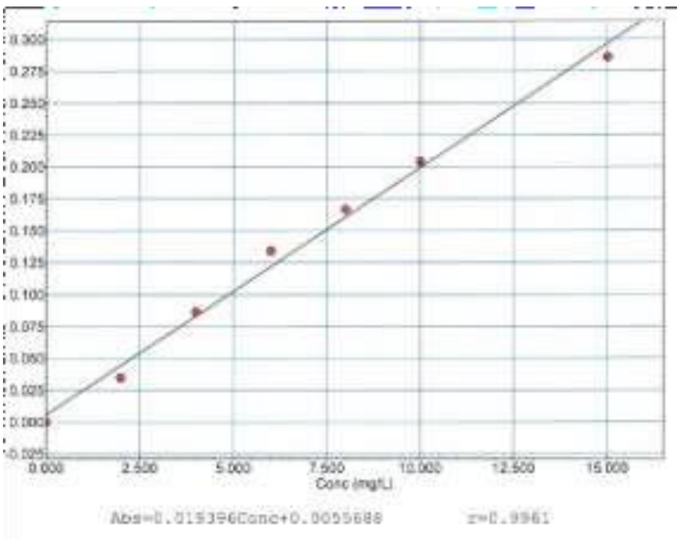
Table 2. Data of Pb (Waste) Metal Uptake results with Chitosan

Cons C0 (mg/L)	Chitosan (g)	Ce [Pb]1	C0 – Ce [Pb]	Q adsorbed	Adsorbed (%)
0,03	0,10	0,0041	0,0259	87,70	0,03
0,03	0,25	0,0036	0,0264	89,93	0,03
0,03	0,50	0,0001	0,0299	95,60	0,03

Description: C0 = Concentration of Metal Pb before adsorption, Ce = Concentration of Metal Pb free in solution, C0 – Ce = Concentration of Metal Pb adsorbed by chitosan, Q = Percentage of uptake = C0 – Ce / C0 x 100% in solution,



Standard Curve of Metal Pb (waste)

The results showed that the higher the chitosan content, the higher the uptake of Pb. The standard value of Pb (waste) obtained from analysis using AAS is 0.03 mg/L, and there is a decrease in Pb levels in the waste to reach 0.0001 mg/L at a chitosan concentration of 0.50%. Anova test results obtained F count (3861.275) > F Table (3.63). With the acquisition of F count greater than F Table strengthens that there is an effect of chitosan concentration and interaction time on reducing Pb levels in waste.

DISCUSSION

Lead is a neurotoxin, entering the human body through breathing and food and drink. In the human body lead (Pb) will be deposited for a long period of time, so it has the potential to adversely affect health, namely disorders of various organ systems. In the nervous system it causes brain damage, in the reproductive system it can cause congenital defects, impaired fertility, as well as in various other vital organs, and the most concerning is the disruption of further child development. Batik waste, especially that generated from the dyeing process, often contains heavy metals such as lead that can pollute the environment. With improper treatment, these harmful substances can seep into groundwater, pollute rivers, and eventually endanger aquatic life and human health. Therefore, finding effective solutions to reduce the concentration of Pb in these effluents is crucial (Abomosallam, Elalfy, Zheng, Nagata & Suzuki, 2022).

Chitosan, a derivative of chitin in shrimp shells, has a high adsorption ability towards heavy metal ions such as lead. This potential makes it a very promising material in waste treatment, especially for the batik industry (Zhang et al, 2021). The results of this study show that chitosan is effective in reducing Pb content, chitosan extracted from fishery waste used as a lead binding agent in batik waste has an increasingly better effectiveness in adsorbing heavy metal Pb as its concentration increases. This paves the way for a more environmentally friendly solution in dealing with batik industry waste. This process not only makes optimal use of previously unused shrimp shell waste, but also addresses the problem of pollution from two sources at once (Keshvardoostchokami, Babaei, Zamani, Parizanganeh & Piri, 2017).

The effectiveness of chitosan as a waste treatment agent can be a safer alternative to other chemical methods that may have additional negative impacts on the environment (Rahmadani, Rozani, Rahmi & Suardi, 2017). In addition, the use of chitosan can also reduce dependence on synthetic chemicals that are commonly used in sewage treatment processes. From a sustainability perspective, the use of chitosan as a binding agent for heavy metals in batik waste could be one way to minimise the negative impact of industry on the environment (Rahman, 2024). Using natural and biodegradable materials such as chitosan not only helps in waste treatment but also supports the concept of circular economy, where waste from one industry can be converted into resources for another industry. This is a significant step towards a more sustainable and environmentally responsible industry (Begum, Yuhana, Saleh, Kamarudin & Sulong, 2021).

This research is expected to encourage innovation in the waste treatment industry, particularly in the textile and batik sector, applying it widely on an industrial scale and offering solutions that are not only efficient but also economical. By using the abundant shrimp shell waste as a source of chitosan, the batik industry can reduce waste treatment costs while still complying with strict environmental standards (Mishra, Islam & Patel, 2013). In a broader context, the success of this research can serve as a model for other industries facing similar problems related to toxic waste. This demonstrates the potential for cross-cutting applications that can provide significant ecological benefits (Liu, Wang, Yu & Meng, 2013; Yan et al, 2018). The positive implications of this research are not only limited to the environment, but also to the local economy. Utilising the abundant and often valueless shrimp shell waste in this study can create added value and new economic opportunities for fishing communities and shrimp processing industries. This could be an example of how local resource-based approaches can strengthen local economies while supporting environmental conservation efforts (Bhatnagar & Sillanpää, 2009; Saravanan, Parthasarathy & Kumar, 2023).

The success of this research will provide strong evidence that green science and technology-based approaches can offer real solutions to complex environmental problems. Combining expertise in materials science, environmental chemistry, and waste treatment technology, this research can be an important milestone in the global effort to reduce the negative impact of industry on the world. The chitosan in this study proved to be effective in reducing the Pb content in batik waste, making this research a valuable contribution to environmental conservation efforts. This research has concretely found a technical solution, but also changed the way we look at managing waste, while focusing on sustainability and environmental responsibility. In an era where sustainability is a global priority, such an approach is necessary to ensure that industrial growth is not at the expense of environmental health.

CONCLUSION

Based on the research conducted, it can be concluded that chitosan adsorbent from shrimp shell is able to adsorb heavy metal Pb in Batik waste with the highest absorption capacity of 95.69% and adsorption capacity of 0.0299 mg/L using 0.5% chitosan adsorbent. The chitosan produced in this study has a degree of deacetylation $\geq$ 90%. Based on the calculation of the degree of deacetylation, it shows that the chitosan produced has met the standard as an adsorbent, because the degree of deacetylation is greater than 60%.

MANAGERIAL IMPLICATIONS

Research on the utilisation of chitosan from shrimp shells in the reduction of Pb in batik waste has significant managerial implications, especially for the textile and batik industries. Company management can consider the application of this technology as part of their environmental sustainability and corporate social responsibility strategies. By adopting this method, companies can not only fulfil increasingly stringent environmental regulations, but also improve the company's image in the eyes of consumers who are increasingly concerned with environmentally friendly business practices. In addition, cost efficiencies can also be gained through the reduction of hazardous waste, which can reduce potential fines and environmental clean-up costs. Therefore, decision-makers in related industries need to consider investing in research and development of these technologies to achieve long-term benefits.

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