

Utilization of hydrothermal technology to process disposable diaper waste into fibers for paving block production

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Abstract

Disposable diaper waste poses a critical environmental challenge, particularly in developing countries like Indonesia, where birth rates remain high. Used diapers decompose very slowly due to their complex composition of plastic, superabsorbent polymers (SAP), and cellulose fibers. This study aims to develop and evaluate the application of hydrothermal technology as an alternative method to convert used diapers into cellulose fibers, which can be utilized as an additive in paving block production. The hydrothermal process was conducted at 150°C and 3–5 bar pressure for 70 minutes using water as the medium. The resulting fiber was then mixed with cement and sand at a ratio of 850 g cement, 2550 g sand, and 600 g fiber. Laboratory tests showed that the produced paving blocks had a compressive strength of 16.8 MPa, water absorption of 6.5%, and a density of 2.2 g/cm³. These results exceed the minimum standard for Class C paving blocks based on SNI 03-0691-1996 (Indonesian National Standard, 1996). These findings indicate that hydrothermal technology not only reduces inorganic waste volume but also produces environmentally friendly construction materials with economic value.

Keywords: Hydrothermal technology; Disposable diapers; Recycled fiber; Paving block; Waste treatment

1. Introduction

The increasing generation of household waste, particularly disposable diapers, presents serious challenges in solid waste management across various regions. Modern diapers are composed of synthetic materials such as polypropylene plastics, SAP polymers, and cellulose fibers, which are not biodegradable. It is estimated that a single child can generate up to 5,000 diapers during their infancy, most of which end up in landfills without treatment. This waste not only pollutes the environment but also carries the potential to spread pathogenic microorganisms that threaten public health.

Conventional diaper waste treatment methods, such as incineration and landfilling, contribute to greenhouse gas emissions and environmental degradation. Hence, innovative and sustainable approaches are urgently needed. Hydrothermal technology offers a promising solution by using water under high temperature and pressure to break down complex materials into simpler components. This method shows high potential for processing disposable diapers into reusable materials such as cellulose fiber for construction applications (Widayat, Kurniawan & Mulyana, 2021).

Research objectives

The objectives of this study are to:

- Analyze the performance of hydrothermal machines in decomposing disposable diapers into cellulose fibers.

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- Evaluate the physical characteristics of paving blocks containing hydrothermal-processed fibers.
- Assess the potential for applying hydrothermal technology as an alternative household waste treatment method at the community or small-industry scale.

2. Research methods

2.1. Materials and Equipment

This study utilized 20 used disposable diapers, 4 liters of clean water, Type I Portland cement (850 g), fine sand (2550 g), and cellulose fibers produced through hydrothermal processing (600 g). The main equipment used was a 70-liter hydrothermal reactor equipped with a digital temperature controller, pressure gauge, and electric motor stirrer. Other tools included a cement mixer, digital scale, 10×20 cm paving molds, and testing instruments for compressive strength and water absorption.

2.2. Hydrothermal Procedure

Used diapers were cut into smaller pieces to accelerate the reaction, then placed into the reactor along with water. The reactor was sealed and heated to 150°C at a pressure of 3–5 bar for 70 minutes.

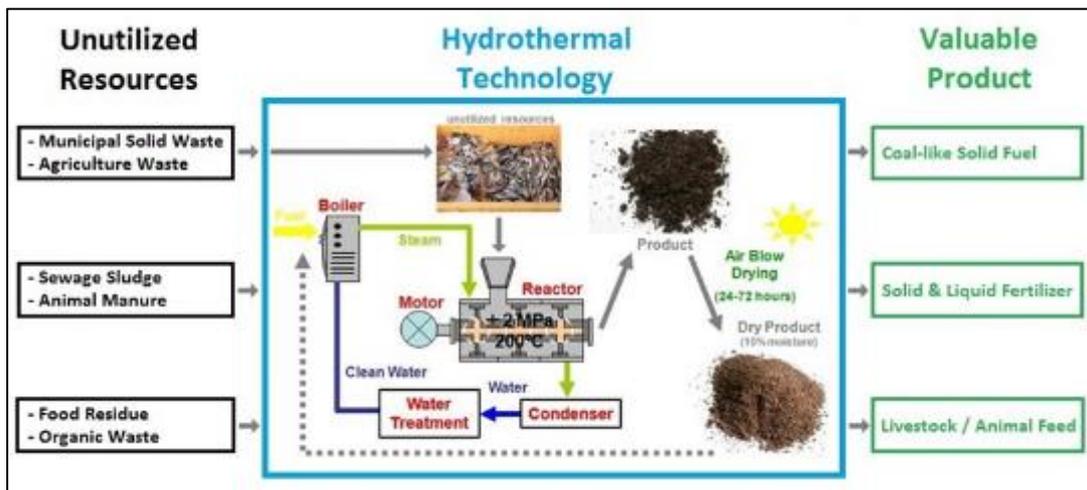


Figure 1 Hydrothermal reactor used for decomposing disposable diapers

After processing, the mixture was cooled and filtered to separate the cellulose fiber from plastic residues.



Figure 2 After the retention time and steam release are completed, the process yields a uniform (homogeneous) sludge product

The fibers were then thoroughly washed and sun-dried until reaching an appropriate moisture level for use.



Figure 3 Cellulose fiber obtained from hydrothermal processing

2.3. Paving Block Production

The resulting fibers were mixed with cement and sand in the specified composition. The mixture was blended until homogeneous (Putri & Nurhidayah, 2021; Yuliani & Ramadhan, 2020), molded into paving shapes, compacted, and then cured in a humid environment for 7 days.



Figure 4 Mixing and molding process for paving blocks

2.4. Physical Characteristics Testing

The paving blocks were tested for the following properties:

- Compressive strength: tested using a hydraulic press until failure occurred.
- Water absorption: determined by soaking the blocks for 24 hours, then comparing dry and wet weights.

- Density: calculated as the ratio of mass to volume.

3. Results and discussion

3.1. Effectiveness of the Hydrothermal Process

The hydrothermal process effectively decomposed disposable diapers into cellulose fiber. The resulting material was light brown, odorless, and had a soft texture. Plastic and SAP components were well-separated, allowing easy manual sorting. The process was efficient and did not produce hazardous liquid waste, as water was used solely as the reaction medium.

This reactor system can be adapted for community-scale use by utilizing alternative fuels such as used cooking oil or waste lubricant oil, making it both sustainable and environmentally friendly.

3.2. Paving Block Characteristics



Figure 5 Finished paving blocks containing hydrothermally derived fiber

Test results showed that paving blocks made with added cellulose fiber had a compressive strength of 16.8 MPa, exceeding the minimum standard for Class C paving blocks as per SNI 03-0691-1996 (Indonesian National Standard, 1996). The water absorption rate of 6.5% indicated low porosity, contributing to enhanced durability under extreme weather conditions. A density of 2.2 g/cm³ made the blocks relatively lightweight, improving efficiency in transportation and installation.

The addition of cellulose fiber enhanced cohesion between particles and reduced micro-crack formation. These findings align with previous studies (Putri & Nurhidayah, 2021; Yuliani & Ramadhan, 2020), which stated that waste fiber improves the mechanical resilience of construction materials.

4. Conclusion

This study demonstrates that hydrothermal technology is an effective method for processing disposable diaper waste into cellulose fiber, which can be used as a construction material additive in paving block production. The resulting paving products exhibited good technical properties and are viable as environmentally friendly construction alternatives. Moreover, this technology offers a sustainable solution for reducing inorganic household waste.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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