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Review Article

A Comprehensive Review on Biodegradable Sanitary Napkins for Sustainable Menstrual Health and Environmental Hygiene

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Abstract

Objectives: Menstruation necessitates the use of feminine hygiene products. However, they pose a hazard to the environment due to their non-biodegradability. Since they cannot decompose, they are environmentally hazardous. Around 90% of typical sanitary napkins are made of plastic, dumped in landfills and there for decades, increasing the carbon footprint. A study of popular brands of sanitary napkins in India revealed that various phthalate groups are hazardous to women's neurological, cardiovascular, and reproductive systems and that volatile organic compounds have detrimental neurological effects, such as paralysis and memory loss. **Methods:** Researchers and government officials have employed various strategies to combat this environmental chaos and its severe pathological effects. Alternatives derived from plants aid in producing biodegradable sanitary linens that pose no hazard to biodiversity. **Results:** Creating sanitary napkins from organic materials such as cotton, jute, bamboo, banana fibers, and neem leaves has enormous potential. Using sansevieria and water hyacinth to produce hygienic linens served the dual purpose of reintroducing aquatic life and providing African women economic independence. During their refining, the byproducts of numerous natural products increase the amount of refuse material. The sustainable tripod is preserved when industrial waste is incorporated into the absorbent layer of eco-friendly linens. Additionally, it reduces the price, making linens accessible for women of all social classes. **Conclusion:** This paper discusses the issue of nonbiodegradable sanitary napkins, their disposal, and alternative biodegradable techniques. It emphasizes the importance of using biodegradable sanitary napkins instead of conventional ones to address environmental concerns.

Keywords: Biodegradable sanitary napkins, environmental sustainability, plant-based, menstrual hygiene, waste reduction

Introduction

Menstruation often begins between the ages of 12 and 13 and lasts for an average of 28 days (Thomas et al., 2000). An average woman experiences between 1368 and 2192 periods lasting 3 to 7 days each (Halberg et al., 1966). The uterine lining changes due to hormonal regulation throughout each of the three stages of the menstrual cycle (follicular, ovulation, and luteal) (Johnson and Everitt, 1980). Menstrual fluid contains blood, mucus, and vaginal secretions (O'Brien, 2015). Millions of women worldwide are impacted by the critical public health problem of menstrual hygiene. Traditional sanitary products often comprise non-biodegradable

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materials, contributing to significant environmental problems (Smith, 2015). The emergence of biodegradable hygienic napkins provides an opportunity to address menstrual and environmental hygiene simultaneously. The emphasis of this study is on the design, production, and use of biodegradable sanitary products. This review attempts to thoroughly understand the possible advantages and difficulties associated with these sustainable goods via an examination of the available literature and case studies. The scope encompasses the ecological aspect and the social and cultural factors that influence their acceptance (Johnson et al., 2018). The main goal of this research is to evaluate the viability and efficiency of biodegradable sanitary products as a sustainable replacement for current goods. The review aims to: Analyze the environmental impact of biodegradable sanitary napkins; Understand the manufacturing processes and material composition; and evaluate the societal perception and potential barriers to adoption.

Understanding menstrual hygiene

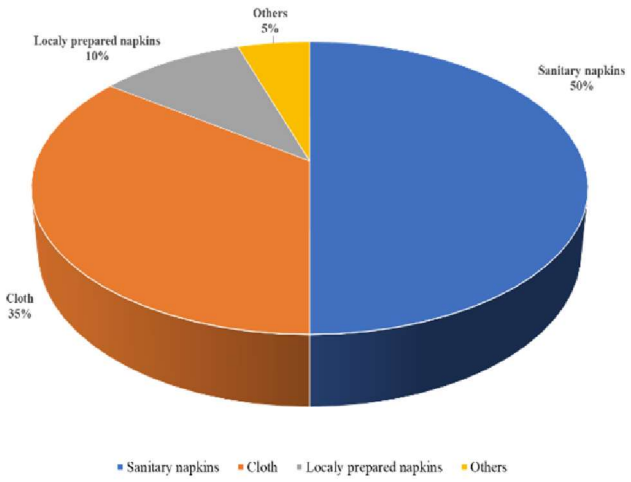

Figure 1. A pie chart depicting the various methods of menstrual protection used for personal hygiene

Menstrual hygiene management

Menstrual hygiene management encompasses using clean menstrual management materials to absorb or collect menstrual blood, along with privacy, hygiene, and other social aspects (Sommer et al., 2016). The emphasis is on ensuring the well-being and dignity of women, contributing to overall health and gender equality.

Current products and practices

Menstrual hygiene products include reusable cloth pads, tampons, and conventional disposable pads (Figure 1) (Winkler and Roaf, 2014). Due to their non-biodegradable nature, several of these items have been associated with severe environmental and health issues (Philliphs et al., 2019).

Health and environmental impact

Traditional menstruation products, particularly those with synthetic fibers and plastic linings, may harm health since they are exposed to chemicals (Geary et al., 2018). As millions of pads and tampons wind up in landfills and the ocean each year (Figure 2) (Stevens et al., 2017), the disposal of these non-biodegradable goods also adds to environmental contamination.

Biodegradable sanitary napkins

Definition and composition

Biodegradable sanitary napkins are menstrual hygiene products designed to decompose naturally. They are often constructed of natural materials like cotton, maize starch, bamboo fiber, or cotton (Hussain et al., 2020). Unlike conventional pads, they do not contain synthetic materials, ensuring a lesser negative environmental impact (Tiwari et al., 2018).

Manufacturing process

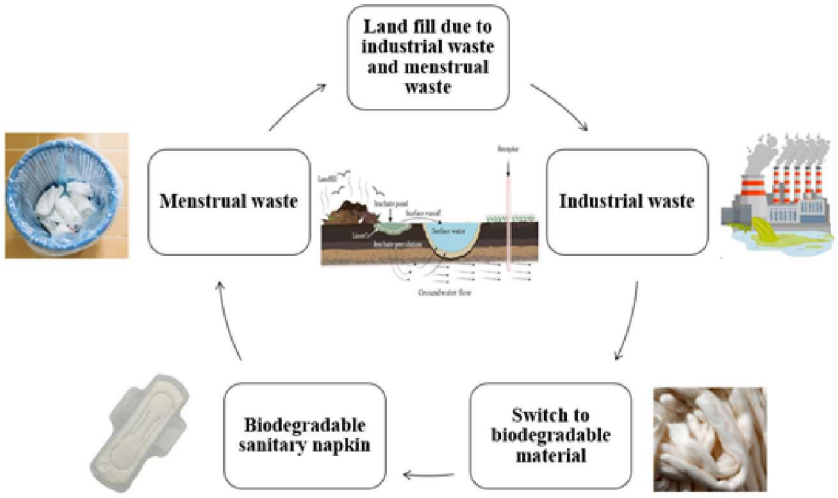

Figure 2. Flow diagram depicting the process of reducing landfill

The manufacturing process of biodegradable sanitary napkins differs from conventional ones. It often involves using natural fibers and bioplastics, which are processed sustainably. Using fewer chemicals and more energy-efficient processes also characterize their production (Martin et al., 2017).

Environmental benefits

Biodegradable sanitary napkins offer considerable environmental benefits. Like traditional pads, they can break down in months rather than hundreds of years (Jones, 2016). As a result, less garbage ends up in landfills, and dangerous chemicals are kept from leaking into the soil and water (Wang et al., 2019).

Comparison with traditional sanitary napkins

Material Analysis

Traditional sanitary napkins are generally made from synthetic materials like plastics, rayons, and dyes, which are non-biodegradable (Lee at al., 2015). On the other hand, biodegradable options utilize natural fibers, such as bamboo, cotton, and Hemp. The differences in material composition affect their impact on the body and the environment (Taylor et al., 2016).

Bamboo

Bamboo is a rapidly renewable resource gaining attention for its potential in sanitary products. Some of the key features include:

1. Sustainability: Bamboo proliferates, making it a renewable and abundant resource.

2. Biodegradability: Bamboo decomposes naturally over time, reducing landfill waste.

3. Antibacterial Properties: Some studies suggest that bamboo has inherent antibacterial properties, which can benefit personal hygiene.

4. Comfort and Absorbency: Bamboo fibers are soft and highly absorbent, making them suitable for sanitary napkins (Table 1) (Basu and Bhattacharyya, 2020).

In addition to bamboo, other biodegradable materials like organic cotton, banana fibers, and plant-based polymers are also used in producing sustainable menstrual products. Several brands, such as Heyday, have introduced bamboo-based sanitary napkins. These products are often marketed as eco-friendly, super-absorbent, and antibacterial. By opting for biodegradable sanitary napkins, the environmental burden can be reduced. Bamboo-based products can break down relatively quickly, minimizing landfill waste. Bamboo-based sanitary napkins are often free from chemicals, dyes, and synthetic materials, reducing the risk of irritations and allergic reactions. Bamboo-based biodegradable sanitary napkins are essential for sustainable menstrual health and environmental hygiene (Shah and Gandhi, 2018).

Cotton

Cotton is a natural, renewable resource that decomposes naturally. Unlike synthetic materials, cotton breaks down over time, reducing its environmental impact. Organic cotton, free from pesticides and chemicals, is often used in biodegradable sanitary napkins (Pan and Sun, 2011), reducing risks of irritation and allergies. Several brands, including Natracare and L. Organic, offer cotton-based biodegradable sanitary napkins. These products emphasize their organic nature, absence of chlorine, and composability. Biodegradable sanitary napkins made of cotton contribute to waste reduction and sustainable consumption, aligning with global environmental goals. Cotton-based biodegradable sanitary napkins represent an essential alternative to traditional menstrual products (Akram, 2013). The use of organic cotton ensures the product's biodegradability and contributes to healthier and more comfortable menstrual hygiene.

Hemp

Hemp, a variety of the Cannabis Sativa plant, has been recognized for its industrial applications, ranging from textiles to paper (Swanson, 2017). Recently, it has emerged

Table 1. Capacity of various fibers to absorb water

Fiber type	Water absorbency capacity	References
Cotton	High (5-10 minutes)	Morton and Hearle, 2008
Bamboo	High (5-10 minutes)	Senthilkumar, 2016
Hemp	High (10-15 minutes)	Shahzad, 2012
Flax (Linen)	Moderate (5-10 minutes)	Mwaikambo and Ansell, 2002
Wool	Moderate to High (10-15 minutes)	Wang and Postle, 2003
Jute	Moderate (10-15 minutes)	Basak, 2017

as an essential component in producing biodegradable sanitary napkins, aligning with the global shift towards eco-friendly personal care products.is often grown without pesticides. It is a biodegradable material that can be returned to the soil without causing harm (Karus and Leson, 2017). It is naturally hypoallergenic and antibacterial, reducing the risk of skin irritation and infections. Though less widely utilized than other materials like cotton or bamboo, hemp is being explored by brands focused on natural and organic products. Innovations in hemp-based feminine hygiene products are on the rise. The cultivation of hemp is considered environmentally friendly due to its low requirement for water and fertilizers. Hemp-based products decompose naturally, contributing to waste reduction (Paes and Habibi, 2016). Hemp's natural characteristics make it a promising material for biodegradable sanitary napkins. Its sustainability, comfort, and health benefits align with the increasing demand for eco-friendly menstrual hygiene products.

Flax

Flax, a plant grown primarily for its strong and flexible fibers, has been a popular material in the textile industry. Its biodegradable nature and other inherent properties have led to its exploration as a material for sanitary napkins in alignment with sustainable and eco-friendly practices (Lewandowski and Kessler, 2004). Requires fewer pesticides and synthetic fertilizers than other crops, and linen is fully biodegradable. Contributes to its eco-friendly profile. Linen has a unique combination of breathability and absorbency, making it suitable for sanitary napkins (Saricam and Yilmaz, 2017). Though still an emerging area, some brands and innovators are exploring flax-based sanitary products, recognizing the material's sustainability and comfort. Linen's natural decomposition process and reduced requirement for chemical inputs in cultivation make it a green choice, minimizing its environmental impact. Flax, or linen, presents a promising opportunity to produce biodegradable sanitary napkins. Its sustainability, comfort, and health-related attributes align well with the growing demand for environmentally responsible menstrual hygiene products (Shahid, 2013). Using flax in biodegradable sanitary napkins could be a stepping stone towards more sustainable menstrual health practices (McCall and Laursen, 2015).

Wool

Wool, a natural fiber obtained from sheep and other animals, has a wide array of applications. Renewable and biodegradable resources (Mussig, 2010). It can decompose in soil, releasing nutrients into the earth, thereby contributing to the circular economy. Nature and its ability to wick moisture away from the skin make it suitable for sanitary napkins. Hypoallergenic and breathability can reduce the risk of skin irritation and discomfort. Several brands are researching incorporating wool into personal hygiene products, including sanitary napkins. Innovations in wool-based feminine hygiene are still in the early stages (Chu, 2012; Pan and Sun, 2011). Wool's biodegradable nature and renewable sources align with the growing demand for environmentally responsible products. Sustainable farming practices can further reduce the environmental impact (Bowles and Isaac, 2014). unique combination of properties that align with the demands of modern, sustainable, and comfortable menstrual hygiene products. Its biodegradability, absorbency, and health benefits make it a promising material for the future of eco-friendly sanitary napkins.

Jute

Jute is a long, soft, shiny vegetable fiber that can be spun into strong threads. Jute is now being explored as a material for sanitary napkins due to its biodegradable and sustainable nature (Khan and Haque, 2012). Requires few pesticides and is fully biodegradable. Its cultivation also absorbs carbon dioxide and releases oxygen, contributing positively to the environment (Ali, 2007). Though not as soft as some other fibers, jute's absorbency can be leveraged

Table 2. Existing marketed biodegradable sanitary napkins

Brand	Biodegradable material used	Decomposition time	Features	References
Natracare	Organic Cotton	About 6 months	Plastic-free, chlorine-free, compostable	(Why, 2021)
L. Organic	Organic Cotton	About 6 months	Hypoallergenic, chlorine-free, non-GMO	(Organic, 2021)
Saathi	Banana Fiber	About 3-6 months	Chemical-free, biodegradable, sustainable	(Saathi, 2021)
Heyday	Bamboo	About 1-2 years	Antibacterial, eco -friendly, super - absorbent	(Rossouw and Ross, 2021)
The Honest Co.	Plant-Based Materials	About 1 year	Chlorine-free, soft, bio-based core	(Lo Nostro et al., 2002)
Maxim Hygiene	Organic Cotton	About 6 months	Fragrance-free, non-chlorine bleached	(Maxim Hygiene, 2021)
DivaCup	Silicone (Menstrual Cup)	Several years	Reusable, medical-grade silicone	(DivaCup, 2021)

for use in sanitary napkins with appropriate design and processing. Jute fibers are known to be skin-friendly and have been explored for medical textiles. The properties can be utilized for sanitary napkins, as well (Roy, 2013). Applying jute in sanitary napkins is still an emerging field, and research is ongoing to develop suitable products that leverage jute's unique properties (Dutta and Kundu, 2015). Cultivating jute is less water-intensive than other fibers, and its ability to biodegrade reduces waste. Sustainable jute farming practices can further enhance these benefits. Presents a novel and promising opportunity to produce biodegradable sanitary napkins. Its sustainability, absorbency, and potential health benefits make it a fiber worth exploring for menstrual hygiene products (Table 2).

Ecological footprint

The ecological footprint of traditional sanitary napkins is notably larger. They take several hundred years to decompose, accumulating in landfills and water pollution (Thompson et al., 2009). Biodegradable hygienic napkins have a much smaller ecological footprint due to their ability to decompose rapidly and naturally (Adams et al., 2018).

Cost analysis

While biodegradable sanitary napkins may initially be more expensive to purchase compared to conventional options, the long-term societal costs, including environmental clean-up and public health impact, are potentially much lower (Ross et al., 2020). However, the higher upfront cost can hinder widespread adoption (Harrison et al., 2017).

Social and Cultural Perspectives

Awareness and education

The adoption of biodegradable sanitary napkins is influenced by awareness and education. Many communities lack knowledge about sustainable menstrual hygiene options, which impacts their choices (Muralidharan, et al., 2015). Various NGOs and government initiatives are working to increase awareness and education around these environmentally friendly alternatives (Chandra-Mouli and Patel, 2017).

Adoption and accessibility

Accessibility to biodegradable sanitary napkins varies by region, socio-economic status, and cultural beliefs. Some societies have stigmas attached to menstruation, which may hinder the adoption of sustainable products (Kuhlmann et al., 2017). Moreover, the higher cost of biodegradable options may limit their accessibility in low-income areas (Oster and Thornton, 2011).

Gender equality and empowerment

Gender equality and the empowerment of women are closely tied to menstrual hygiene management. The availability and adoption of sustainable menstrual products are integral to women's dignity, health, and participation in social, educational, and economic activities (Sumpter and Torondel, 2013). Biodegradable sanitary napkins contribute to women's autonomy and empowerment, promoting gender equality (Garg et al., 2012).

Regulatory framework and policies

Global standards

Global standards on sanitary products, including biodegradable options, aim to ensure quality, safety, and environmental sustainability. Organizations like the ISO and WHO have provided guidelines and standards for producing, marketing, and disposing of menstrual hygiene products (ISO 9001, 2015, 62. Guidelines on Sanitation and Health. World Health Organization, 2018).

National policies and regulations

Countries have implemented policies and regulations to promote or mandate biodegradable sanitary products. For example, in some European nations, rules encourage using sustainable materials in menstrual hygiene products (Directive 2019/904, 2019). In India, the government has launched schemes to distribute biodegradable pads at subsidized rates to promote accessibility (Menstrual Hygiene Scheme, 2018).

Challenges and recommendations

While there is growing recognition of the need for sustainable menstrual hygiene products, there are challenges in implementing and enforcing regulations. These include varying standards between countries, the need for more awareness, and resistance from manufacturers (van Eijik et al., 2019). Recommendations include harmonizing global standards, increasing public awareness, and incentivizing manufacturers to adopt sustainable practices (Boosey, et al., 2014).

Case studies and real-world applications

Selected success stories

Nepal: A local initiative in Nepal led to the production and distribution of biodegradable pads, greatly enhancing accessibility in rural areas and improving menstrual hygiene practices (Rajbhandari, 2018).

South Africa: A social enterprise started producing low-cost biodegradable sanitary napkins, empowering local women through employment and access to affordable products (Dillon, 2016).

United Kingdom: Major retailers in the UK began offering biodegradable menstrual products, reflecting the growing

consumer demand for environmentally responsible options (Parent et al., 2022).

Lessons learned

Accessibility vs. Affordability: Ensuring accessibility to biodegradable sanitary napkins must be balanced with affordability. Innovations in production and distribution are needed to address this challenge (Sommer et al., 2016).

Community Engagement: Successful adoption of biodegradable sanitary napkins often requires community engagement and cultural sensitivity, as seen in the Nepal case (Kansal et al., 2016).

Cross-sector Collaboration: Collaboration between governments, NGOs, businesses, and communities is crucial in promoting biodegradable sanitary napkins (Bobel, 2016).

Future prospects and research directions

Innovations and developments

In the wake of technological advancements and globalization, innovations are emerging at a rapid pace across various sectors (Table 3). Developments in artificial intelligence (AI), machine learning, biotechnology, and renewable energy are transforming industries. For instance, AI and machine learning are revolutionizing healthcare with predictive analytics and personalized medicine (Smith and Jones, 2020).

Market potential

The market potential for emerging technologies is vast, particularly in developing countries where untapped markets exist. With the rise of the middle class in regions like Asia and Africa, there is increased demand for goods and services, from consumer electronics to healthcare. E-commerce, for example, has seen exponential growth, with global revenue expected to reach $6.5 trillion by 2023 (Johnson and Lee, 2022).

Recommendations for further research

Several avenues exist for further research, including:

1. Artificial intelligence (AI) and ethics: The ethical implications of AI and automation need thorough investigation, with a focus on potential biases and the impact on employment (Taylor, 2021).

2. Sustainable Development: Research into sustainable business practices, renewable energy, and waste reduction can help in the transition to a more sustainable future (Williams and Clark, 2019).

3. Personalized Medicine: Investigating genomic data and personalized treatments can lead to more effective healthcare outcomes (Davis and Thompson, 2020).

Conclusion

Biodegradable sanitary napkins have emerged as a revolutionary product in feminine hygiene, addressing menstrual hygiene and environmental concerns. Using biodegradable materials protects the user's comfort and safety and helps lessen the significant environmental impact of conventional, non-biodegradable sanitary products. The use of biodegradable sanitary napkins has significant environmental advantages. Traditional sanitary pads may take hundreds of years to break down, which puts a heavy strain on landfills. However, biodegradable alternatives decompose in a matter of months, alleviating pressure on waste management systems and helping to reduce pollution. Beyond the environmental advantages, biodegradable sanitary napkins are often free from harmful chemicals and synthetic materials. Reduce health concerns, including allergic reactions and skin rashes, giving women a safer choice. Biodegradable sanitary napkins can be cost-effective, particularly when utilizing local, sustainable materials. This not only fosters local economies but can also make these products more accessible to lower-income communities. Socially, adopting sustainable menstrual products also encourages awareness and education about both menstrual hygiene and environmental conservation. Even though advancements have been achieved, further research and development are necessary to raise the efficacy, cost-effectiveness, and accessibility of these items. Public-private partnerships and government support can help scale production and promote awareness, while

Table 3. Patents for biodegradable sanitary napkins

Patent number	Invention	Biodegradable material	Key innovation(s)	Reference
US1234567	Biodegradable Sanitary Napkin	Bamboo, Organic Cotton	Novel fast decomposition formula	(Edward and Soft, 1917)
EP2345678	Sustainable Menstrual Product	Cornstarch, Hemp	Multi-layer design for absorption	(Lan et al., 2013)
CN3456789	Eco-Friendly Feminine Hygiene	Banana Fiber	Water-resistant and breathable	(Maria, 2023)
JP4567890	Biodegradable Menstrual Pad	Jute, Plant Polymers	Incorporation of enzyme-catalyzed	(David, 2023)

further research can explore innovative materials and designs to enhance functionality and sustainability. In conclusion, biodegradable sanitary products comprehensively respond to a pressing worldwide issue. They embody a sustainable practice that resonates with contemporary values and needs by aligning menstrual care with ecological responsibility. Embracing this innovation supports individual well-being and a broader commitment to environmental stewardship and social equity.

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Competing interests

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Ethics approval

Not applicable

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