

## Recent Trends in the Research on Sustainable Sanitary Pads

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### ABSTRACT

Menstrual Hygiene Management (MHM) is a basic necessity for women. Although single use sanitary pads have become the most popular way of dealing with menstrual flows, their use remains limited to mostly urban populations. Most women in rural areas, particularly in developing countries continue to depend on unhygienic and unhealthy materials and practices to manage their menstrual hygiene. Lack of awareness as well as accessibility and affordability are perceived to be the main problems in this regard. Interest in sustainable sanitary pads has been triggered because of the adverse environmental impacts caused by the disposal of single use sanitary pads, made from petroleum based raw materials. Health concerns arising out of repeated use of synthetic sanitary pads is another factor, influencing the research on alternative sustainable materials for sanitary pads. The affordability of commercial sanitary pad has also become a major motivation in the developing countries for focusing on low cost and reusable sanitary alternatives. The review aims to explore recent research on sustainable menstrual hygiene management, focusing on factors related to effective menstrual health and hygiene, identifying sustainable alternatives for sanitary pads, assessing the use of low-cost and recyclable materials, and reviewing initiatives to improve the properties of sustainable pads. This review paper provides an overview of the contributions made by researchers in India and other developing countries to create an overall understanding of the initiatives already taken and the remaining challenges in the area of sustainable sanitary pads.

**Key Words :** Sustainable sanitary pads, Menstrual Hygiene Management, Reusable sanitary pads, Low cost sanitary napkins

### INTRODUCTION

The primary purpose of a feminine hygiene product is to effectively absorb and retain menstrual fluid, preventing any backtracking of the fluid, simultaneously ensuring an odour-free experience (Barman, Katkar and Asagekar, 2017). Feminine hygiene products can be either disposable (sanitary napkins, tampons and panty liners) or reusable (menstrual cups, cloth pad). The disposal sanitary products constitute a significant portion of the Indian disposable hygiene market (Sornapudi, Shrivastava, Soni and Jha, 2018).

Sanitary napkins are thin absorbent pads that come in various shapes and sizes to cater to different menstrual flow levels (Kavinkumar *et al.*, 2023). Sanitary napkins must meet various essential criteria, such as high

absorbency and fluid retention, preventing leakages and odors, maintaining an aesthetic appearance, staying securely in place, and offering comfort. Moreover, these products are also expected to enhance women's health and lifestyle (Dhinakaran, Senthil and Sathis, 2017). Indeed, the primary requirements of sanitary napkins are to effectively absorb menstrual fluid, maintain a dry surface by transferring the fluid into the bottom core materials, and retain the absorbed liquid within the core even under external pressure or compression (Chandrasekaran *et al.*, 2020). Soft touch, dry feel, odourless, leakproof and antibacterial properties are the expectations from a sanitary pad (Dobur *et al.*, 2022).

### Challenges in Menstrual Hygiene Management:

However, the sanitary pads usage scenario in India

leaves a lot to be desired. According to a WHO survey in India conducted in October 2017, 43 per cent of women lacked access to sanitary essentials during their periods. Around 67 per cent of women reported having to borrow sanitary products from friends, colleagues, or family members. Additionally, 45 per cent stated that they had to borrow sanitary napkins at least once or twice a year. The survey also highlighted that more than 45 per cent of women considered menstruation a taboo in society, and 32 per cent felt uncomfortable buying sanitary products from a chemist shop in the presence of other customers (Chatterjee, 2018). In India, there are approximately 380 million rural females, most of whom do not use sanitary napkins due to lack of awareness and accessibility. Another concern is that the majority of rural females do not wear undergarments, which poses a significant challenge for promoting the use of sanitary napkins. Thus, the first step would be to raise awareness about the advantages of wearing undergarments, followed by promoting the benefits of using sanitary napkins (Shrivastava, 2013). As of now, around 48% of Indian women still use cloth during their periods, but there is a gradual acceptance of sanitary napkins, even in rural areas. However, due to the prevailing taboo and stigma around menstruation in the country, many women are still hesitant to use proper hygienic sanitary products. Some villages continue to follow long-forgotten traditions, such as using ash, soil, or dried leaves to soak menstrual blood, leading to health problems among women. It highlights the need for increased awareness and education on menstrual hygiene to improve women's health and well-being (Bhor and Ponshe, 2018).

Lack of awareness and poverty continue to be major hurdles on the way of menstrual hygiene. 'Period poverty' refers to the lack of access to sanitary napkins and proper toilet hygiene for women. This situation arises due to financial constraints, preventing many women from obtaining essential menstrual products and adequate sanitation facilities during their periods (Banappagoudar, 2021). Qualitative studies indicate that some girls prefer conventional sanitary pads, but many are unable to access or afford them (Ghosh *et al.*, 2020). Females from low-income families often find sanitary pads prohibitively expensive, leading them to resort to crude and inexpensive methods for managing their menstrual needs (Chakwana and Nkiwane, 2014). As a result, women often face significant challenges in managing their menstrual hygiene, leading to potential health risks and social barriers

(Banappagoudar, 2021). The unaffordability of sanitary products also hinders girls' active participation in school, as they often miss classes due to unreliable traditional options, lack of private changing areas, poor water and sanitation facilities, and inadequate disposal methods. Consequently, menstrual hygiene products are often improperly disposed of, leading to environmental pollution (Foster, Jasmin and Montgomery, 2021).

Due to unhygienic menstrual habits of using unsanitized cloth, husk, sand etc., a large number of women suffer from "reproductive tract infections" that is about 70% in India (Pandey and Dixit, 2016). Traditional methods of managing menstrual bleeding, such as using old clothes, paper, cotton, and leaves, offer unreliable absorbency and increase the risk of infections leading to long-term reproductive issues (Foster, Jasmin and Montgomery, 2021).

#### **Problems with commercially available Sanitary Pads:**

Commercially available menstrual hygiene pads often contain harmful chemicals such as dioxins, petrochemicals, and artificial fragrances. These chemicals can cause skin irritation when they come into contact with sensitive skin tissue. The presence of dioxins in the cellulosic chlorine bleached pulp and rayon used to enhance absorbency can lead to cervical cancer and irregular growth in reproductive organs. Deodorants and synthetic materials in sanitary pads can trap dampness and heat, promoting the growth of yeast and bacteria (Barman *et al.*, 2017; Anbalagan and Mekala, 2021).

Currently, there are many types of sanitary napkins available in the market to absorb the menstrual fluid but most of them are constructed by using petroleum bi-product called SAP and it is used to absorb and hold more menstrual fluid (Chandrasekaran *et al.*, 2020). Superabsorbent polymers (SAPs) are hydrophilic, cross-linked macromolecular networks capable of absorbing and retaining a significant amount of liquid. These three-dimensional networks of cross-linked polymer chains maintain their structure while holding water and remain insoluble in water. SAPs can retain large quantities of liquid by forming a gel, preventing the absorbed liquid from leaking back to the surface of a sanitary napkin. This feature ensures dryness for consumers over an extended period of use (Peng *et al.*, 2020).

Extended use of sanitary napkins, beyond 4 to 5 hours, can lead to vaginal issues like rashes, itching, and bacterial growth due to a warm and moist environment.

Chemicals in the napkins may cause contact dermatitis. Rashes can result from contact dermatitis, where the skin of the vagina becomes irritated by certain layers or materials in the pad, such as the back sheet, fragrance, or adhesives. Sanitary napkins typically contain polyolefins, zinc oxide, and petrolatum in their top and back sheets, which may react with the skin in the vaginal area. It is essential to change sanitary napkins regularly to avoid such issues and maintain vaginal health (Banappagoudar, 2021). While the commercially available disposable sanitary pads offer benefits like easy availability and cost-effectiveness, they can also cause issues like irritation, rashes, and uncomfortable odors due to non-biodegradable chemicals. Excessive use of sanitary pads has been linked to menstrual problems, infertility, PCOD/PCOS, cervical and ovarian cancer, urogenital challenges, hormone imbalance, and vaginal microbial imbalance (Kavinkumar *et al.*, 2023).

#### **Adverse Impacts on the Environment:**

In earlier times, women managed menstruation through environmentally friendly methods, such as isolating themselves during their periods and using natural materials like leaves or cloth. However, as societies evolved, less sustainable menstrual products emerged, leading to environmental concerns due to the increased waste, including menstrual debris (Murthy, Lakshmi, 2015). Disposable sanitary pads contribute to environmental concerns due to the non-biodegradable materials used in their production. Improper disposal methods, such as flushing them along with domestic waste or depositing them in landfills, lead to environmental pollution. Incineration, a common disposal method, also contributes to global pollution. Burying the pads in the ground is not a viable solution either, as the polyethylene plastics used in these pads do not biodegrade and can persist in the environment unchanged for hundreds of years (Chakwana and Nkiwane 2014). Super Absorbent Polymers that have excellent absorbency and waterproof properties but pose environmental concerns due to their non-biodegradable nature (Shri, Shanmuga *et al.*, 2023).

India faces a significant waste load due to disposable napkins, with 1.021 million pads discarded monthly, totaling 12.3 billion annually. This accounts for 113,000 tonnes of menstrual waste generated each year by 121 million women and adolescent girls. The figures highlight the substantial environmental impact caused by disposable napkins' widespread use. The large amounts of menstrual

waste generated emphasize the urgent need for sustainable and eco-friendly alternatives to mitigate these environmental challenges (media.path.org, 2023)

Non-compostable pads' disposal in India poses environmental and health risks, with over a billion discarded monthly. Pune Municipal Corporation's expenses in handling menstrual waste, at 5 INR per pad, have become unsustainable. The city's population of over 1 million women contributes to the high costs of collecting, segregating, transporting, and burning menstrual waste (Bhor and Ponkshe, 2018). Flushing these pads causes sewage blockage, leading to a global issue. Moreover, these pads may carry viruses like hepatitis and HIV if used by infected women. Incineration of menstrual waste releases toxic gases, including carcinogenic dioxins. In light of these drawbacks, biodegradable sanitary napkins made from natural fibers offer a safer and environmentally friendly alternative (Ghosh *et al.*, 2020).

Currently, the world is facing a problem of the carbon footprint from many products including used feminine hygiene products during its disposal. As there is a huge amount of non-biodegradable material dumped in the landfill, which releases harmful gasses into the atmosphere. Female between the age group 15–49 will generate at least half a kilo of used sanitary napkin waste per month (Chandrasekaran *et al.*, 2020). These problems get aggravated during health and natural emergencies. During the COVID-19 pandemic period, rise in poverty led women to explore the reusable product market for affordable and long-lasting alternatives to traditional sanitary products (Achuthan *et al.*, 2021). The use of reusable sanitary towels is well accepted for menstrual hygiene management in non-disaster situations and is appropriate in post-earthquake relief in Nepal. The use of locally available, reusable and biodegradable materials is eco-friendly, empowering, as well as a sustainable and culturally appropriate method for menstrual hygiene management in emergency situations. (Budhathoki *et al.*, 2017).

Since their initial introduction in the early 20th century, disposable feminine hygiene products have primarily focused on improving their functional performance. Only recently have there been a few attempts to create eco-friendly alternatives. However, these alternatives have faced challenges due to their higher costs and lower performance, limiting their market potential compared to traditional disposable products (Carlucci, 2012). Market outlook reports indicate that

reusable sanitary pads make up around 5% to 10% of the global health and personal care market. Disposable pads, on the other hand, contribute to environmental pollution as they end up in landfills or are disposed of through incineration. Considering factors like women's health, equal opportunities, sustainability, and environmental well-being, it is evident that reusable pads are a more sustainable alternative to disposable ones (Dobur *et al.*, 2022).

### Research Objectives:

The primary objective of this review paper is to provide a bird's eye view of the recent researches relating to Sanitary pads in the context of creating sustainable options for menstrual hygiene management and environmental improvements. Specifically, this review paper aims at the following:

1. To review the factors relevant to the effective management of menstrual health and hygiene.
2. To identify the sustainable alternatives used in the development of sanitary pads.
3. To assess the scope for using low cost and recyclable raw materials and reusable final products.
4. To review the initiatives taken to improve the properties of sustainable sanitary pads

## METHODOLOGY

This research is based on a review of 42 research papers extracted from research repositories such as Research Gate, Open Science, Science Direct, Academic.edu, Core, Google Scholar. The review also includes a few other review papers already done on the subject, which extends the coverage of the present review paper to over 200. The 42 papers were selected from a pool of 68 papers based on relevance to the research objectives. One of the striking features of the literature search was that the majority of the papers from developing countries particularly from South Asia and Africa. It had a predominant presence of India research papers. These papers covered a variety of demographic settings such as rural, urban, slums locations, as well as young and older age groups belonging to different income groups. The retrieved research papers were further grouped based on their research goals keeping in view the specific research objectives of this review paper.

## RESULTS AND DISCUSSION

The various studies covered in this review have made distinctive contributions to enlighten some of the key aspects relating to sustainable sanitary pads. The findings are presented below:

### Factors relevant to the effective management of menstrual health and hygiene:

The rapid review by Pednekar *et al.* (2022) explored current MHM practices, awareness levels, and factors influencing sustainable menstrual product use. It revealed valuable insights on promoting eco-friendly options and enhancing menstrual health practices. Studies on menstrual health awareness in rural schools reveal disparities between rural and urban areas due to factors like access to materials, parental discussions, and media influence. Education and media positively impact practices, but challenges in storage and transportation persist due to secrecy, infrastructure, and finances. Comprehensive and culturally acceptable education on menstruation is necessary. Research on menstrual products focuses on feasibility and acceptability, promoting reusable options like banana fiber pads for their biodegradability, reduced leakage, and low CO<sub>2</sub> emissions. Comfort, volume, and absorption are crucial factors in women's choices. Menstrual cups and cloth pads are popular eco-friendly options, but tampons face concerns. Despite environmental consciousness, patriarchal and cultural norms can hinder acceptance. African studies reveal that menstrual cups and reusable pads positively impact schoolgirls, reducing discomfort, leakages, and absenteeism. Menstrual waste disposal and management were examined through surveys in Vanuatu and Asian studies, particularly in India and Nepal. Challenges in rural schools were identified, and the earthquake in Nepal led to the acceptance of reusable pads. Education by various stakeholders is essential for promoting sustainable menstruation and proper waste management (Pednekar *et al.*, 2022).

In Hyderabad, India, 277 women from slums participated in a study, given choices between single-use pads, reusable cloth-pads, or information about menstrual materials. Local NGOs facilitated the research, using interviews before and after to assess attitudes towards menstrual practices. The study aimed to explore whether exposure to sustainable alternatives positively influences preferences over single-use pads. The study highlighted barriers in adopting sustainable menstrual practices due

to the “disposable pad culture.” To promote sustainability, user-friendly innovations, evidence-based messaging, and raising awareness about alternative choices are vital for supporting behavioral changes (Garikipati, Docherty, Phillips-Howard, 2019).

In 2020, a project-based study in India examined menstrual health and hygiene sustainability, focusing on eco-friendly alternatives like cloth pads. The research identified barriers to cloth pad adoption and proposed solutions for menstrual waste. Interviews, surveys, and workshops were used to gather data and involve various stakeholders in assessing India’s menstrual hygiene landscape. The findings emphasized the crucial role played by the Government and cloth pad manufacturers. A comprehensive approach considering waste management, sexual/reproductive health, environment, and gender equality is vital. Cloth pads offer a sustainable alternative, enhancing menstrual health management and benefiting women and the environment (Kaur, 2020).

A study conducted among Udaipur college students in 2018 examines awareness, availability, popularity, adoption, usage patterns, and disposal practices of feminine hygiene products to offer valuable insights for improvement. Study results show limited awareness of tampons and menstrual cups among college-going students, with most preferring ultra-thin pads. Many were aware of environmental hazards and stressed proper disposal as essential (Sornapudi *et al.*, 2018). Another study conducted in the slum areas of Govandi, Mumbai examined factors affecting low-cost sanitary napkin adoption and also explores the barriers, drivers, and sustained acceptance of affordable menstrual hygiene products in the urban community for insights and improvements. The results revealed 62% of women used sanitary napkins, 38% used cloth. Most purchased napkins in the Rs. 28-35 range. 74% felt shy buying napkins, 63% reused cloth, 68% were reluctant to switch. 53% cloth users would switch if offered reasonable rates. 65% satisfied women used napkins, 35% used cloth (Bhatia, 2014).

A study of 500 women conducted in the two villages of Gautam Buddha Nagar, Uttar Pradesh surveyed expectations and preferences for sanitary napkins. Key concerns included absorptivity, leakage prevention, wetness, and odor prevention. Participants desired antibacterial properties, biodegradable covers, and even pain relief in sanitary napkins. The research highlights areas for improvement in napkin design to align with

consumer preferences (Singh *et al.*, 2023).

A study conducted in rural Uganda analyzed data from a controlled trial involving 205 menstruating schoolgirls to assess menstrual hygiene management effectiveness, and found that more than half used improvised methods like cloth, while others used intervention-provided reusable pads. The schoolgirls using reusable pads reported higher perceived absorbent reliability. There were no significant differences in garment soiling or odor between reusable pad users and others. However, reusable pad users avoided certain activities during menstruation more than others (Hennegan *et al.*, 2016).

A review paper covering data from 138 studies involving 193 subpopulations and 97,070 girls in India analyzed menstrual hygiene management (MHM) among Indian adolescents, revealing differences in usage across settings. Urban areas preferred commercial pads, while rural areas used cloths. Economic factors influenced cloth preference, alongside disposal issues and awareness. Urban settings commonly used routine waste disposal and burning, while rural areas preferred burying. Approximately 23% of girls disposed of absorbents in open spaces, more prevalent in community-based studies. Despite the rise of commercial pads in urban areas, menstrual absenteeism remained unaffected after adjusting for region (Van Eijk *et al.*, 2016).

The 3A’s (affordability, accessibility, awareness) significantly influence rural Indian women’s sanitary napkin usage. A survey conducted at Mendua village, Raisen district, India, identifies reasons for non-usage, emphasizing the need for affordability, accessibility, and awareness to promote these products effectively (Shrivastava, 2013).

Another study aimed to assess awareness and perceptions of sanitary napkins among 400 women in Madanpur Khadar, an urban slum in Delhi, sought to evaluate the acceptability of low-priced socially-marketed sanitary napkins among non-users of sanitary napkins in the area. Nearly half of the participants didn’t use napkins due to high costs and difficulties in access and usage. However, if provided at a lower cost, 70% were likely to use napkins, preferring them over cloth (Shaikh *et al.*, 2019).

Sustainable menstrual products are vital for reducing environmental impact, catering to women’s diverse needs. The “Dahini” incinerator offers an affordable solution for proper menstrual waste disposal in Pune, India,

benefiting the community and environment. Its low pollution levels make it a promising option to tackle sanitation challenges effectively (Bhor and Ponshe, 2018). A study explored factors influencing sanitary napkin usage among 14,625 adolescent girls in Uttar Pradesh and Bihar using data from the UDAYA 2016 project survey. The findings suggested that the education level, engagement in paid work, exposure to mass media, and higher wealth quintiles positively impacted napkin use. However, community-level education of mothers did not significantly influence menstrual hygiene practices among adolescents (Chauhan *et al.*, 2021).

### **Sustainable alternatives used in the development of sanitary pads:**

An experimental research developed and characterized sanitary napkins using regenerated cellulose fibers Lyocell and Modal. The sanitary napkins made from Lyocell, Modal, and their blend were compared with commercially available sanitary napkin brands for dimensional and performance parameters. Lyocell and a 50/50 blend of Modal and Lyocell sanitary napkins showed the highest absorption capacity, wickability, and lowest liquid strike-through time. Lyocell napkins were thinner and exhibited better antibacterial activity compared to the blend and 100% Modal (Dhinakaran, Senthil and Sathis, 2017).

Another study quantitatively analyzed a novel banana fiber-based menstrual pad (BFP) among 155 rural and 216 urban participants in India. Participants in the study showed satisfaction with the novel banana fiber-based menstrual pad (BFP), recommending it to others. User preferences were influenced by concerns for the environment, health, and cost. The BFP is deemed a promising and eco-friendly alternative for managing menstrual hygiene in densely populated countries like India, providing a non-invasive and reusable option preferred by users (Achuthan *et al.*, 2021).

A review exploring the chemical composition and properties of plant fibers like jute, bamboo, bananas, kenaf, hemp, water hyacinth, and flax, to assess their potential as alternative raw materials for manufacturing sanitary napkins, highlighted Lignocellulosic plant fibers as renewable, biodegradable, and environmentally friendly alternatives that have the potential to replace synthetic and man-made fibers in this context (Anbalagan and Mekala, 2021).

Another research aimed to create a biodegradable,

sanitized pad as an eco-friendly alternative to commercial sanitary napkins with synthetic superabsorbent polymers (SAP). Six models were designed using biopolymers for the absorbent core layer. Investigations standardized absorption, fluid retention, and coziness. Sodium alginate and CMC show promise as SAP replacements, and neem-treated outer layers exhibit antimicrobial properties against bacteria (Moynul *et al.*, 2022).

An experimental research by Pandey and Dixit replaced traditional cotton filler in sanitary napkins with flax spinning byproduct, a cost-effective and highly absorbent material. Aloe Vera gel's methanolic extract treated with the core sheet, resulted in significantly improved antimicrobial potential against *S. aureus*. The napkins met required size, shape, thickness, and absorbency standards. Evaluators, including college girls, working women, and housewives, rated the napkin positively for comfort-related features (Pandey and Dixit, 2016).

Another research focused on creating sustainable feminine hygiene products that met functional requirements (absorbency, dryness, flexibility, comfort) while minimizing material usage and waste generation. The study focused on developing a bio-based super absorbent material with high menses absorption capabilities to replace or reduce synthetic SAP materials. Bio-based polymers, particularly cationic starches, demonstrated promising results in terms of cost-effectiveness, safety, and performance. They interacted with menses components, creating a highly absorbent gel, surpassing the absorption capacity of standard SAP materials. The new sustainable product features a multilayer core structure with optimized component design, facilitating component synergies (Carlucci, 2012).

The Research paper by Kavinkumar et al advocates affordable, biodegradable, and healthy sanitary napkins to promote environmental sustainability. The paper suggests using Eco-friendly alternatives include jute, milkweed, banana, and bamboo fibers with added antibacterial properties from tulsi, aloe vera, and curcuma. Jute, mint, aloe vera, and natural substances like orange peel, jasmine, and rose provide antibacterial properties and odor control. As per the study, biodegradable materials like PLA and SPF, cellulose-based hydrogels with sodium alginate and CMC, and cellulose acetate nanofibers provide improved napkin absorbency. Anionic pads with saponin and aloe vera components improve airflow (Kavinkumar *et al.*, 2023).

Sabrina Sareen's review paper examines research conducted over the past decade on biodegradable materials as alternatives to disposable plastic napkins. The review discusses genetic engineering of biodegradable polymers, antibacterial nano-colorants, cellulose-based hydrogels, and eco-friendly fibers like soybean, bamboo, and banana. Herbal antimicrobial extracts are explored for skin-friendly napkins, and sustainable pads are created from knitwear industry waste and bamboo wadding fabrics. The focus is on finding solutions to the increasing waste menace worldwide (Sareen, 2021).

A recent experimental research developed biodegradable sanitary pads using Kenaf and Chitosan fibers. Both these fibers contain anticancer, antioxidant, analgesic, and antibacterial properties. They also degrade faster, and perform well in tests compared to commercial pads. Carded fibers serve as the absorbent core, making them eco-friendly alternatives (Jeyakanthan, Schuster, and Shaik, 2023).

The moisture behavior in a sanitary napkin using 100% natural milkweed fibers as the core absorbent with polyethylene and polypropylene layers was studied in a research study by Chandrasekaran *et al.* Milkweed and milkweed/cotton blended sanitary napkins offer improved moisture behavior properties compared to cotton napkins. They show lower initial spreading rates, enabling vertical wicking for even liquid distribution and reduced skin contact with wet areas. Milkweed's hollow structure contributes to superior liquid retention and absorption, making it suitable for eco-friendly and non-allergenic medical textiles (Chandrasekaran *et al.*, 2020).

Another study developed and characterized natural polysaccharide-based superabsorbent polymers (SAPs) from chia seeds, chia flour, and Mimosa pudica hydrogel for use in sanitary napkins. Performance tests, antibacterial property, and biodegradability evaluations were conducted. The study found that Mimosa pudica hydrogel (MPH) had the highest absorption capacity (5.24 g/g) and lowest re-wet value (1.58 g), making it a superior superabsorbent polymer (SAP) compared to chia seeds and chia flour. MPH also showed potential for antibacterial properties and biodegradability, making it a promising SAP for use in sanitary napkins (Peng *et al.*, 2020).

In a study done by Petchimuthu, et al, naturally available and cost-effective materials, banana fiber, and cotton, were used to create biodegradable sanitary napkins. The napkins exhibited desirable properties like

porosity and effective fluid retention. The sanitary pad is designed with a multilayered structure, each layer serving a specific function. The core is made of banana fiber sheet, surrounded by organic cotton, and covered with a layer of Muslin cloth. The entire setup is then wrapped with a Canvas cloth for added protection and comfort. The distributed sample napkins received positive feedback from the villagers who reported that the product had an absorbency capacity of up to 5 hours, and that they did not experience any rashes or foul smells while using it (Petchimuthu *et al.*, 2019).

A research done in 2023 aimed at analyzing the absorbent properties of available biodegradable fibers such as cotton, bamboo, hemp and pina to replace the absorbent polymers in menstrual hygiene products. The results showed that bamboo had a higher absorbent capacity compared to the other fibers. Therefore, bamboo is considered a preferable option for replacing absorbent polymers in menstrual hygiene products (Shri, Shanmuga *et al.*, 2023).

Another research introduced a method for creating the absorbent core of an ultra-thin sanitary napkin using blends of viscose and super absorbent fiber (SAF) with different SAF percentages and mass per unit area ( $g/m^2$ ) of the absorbent core. The viscose/SAF blended webs were placed between two layers of nonwoven fabric to integrate and encapsulate them (Das *et al.*, 2008). A review article by Ghosh et al focusses on the development of biodegradable sanitary napkins made plant fibres such as jute, banana, cotton, water hyacinth, and bamboo. The review provides insights into the eco-friendly alternatives for menstrual hygiene products currently accessible to consumers. The study also emphasizes the need for creating greater awareness of these biodegradable sanitary napkins (Ghosh *et al.*, 2020).

### **Scope for low cost and recyclable raw materials and reusable final products:**

Gramalaya, a Tamil Nadu-based organization, distributes low-cost, reusable cloth pads free from dioxins, plastic chemicals, and pesticide residue commonly found in chlorine-bleached disposable pads. This initiative has enabled 40 women from 40 households to earn a livelihood, benefiting them directly. Additionally, around 20,000 women and girls are using these environmentally friendly pads (Chatterjee, 2018).

The Zimbabwe project in 2014 aimed to develop an affordable and reusable sanitary pad using polyester

microfiber materials. The reusable microfiber sanitary pad is more durable and offers resistance to microbial attack. The strength of polyester microfibers allows for increased longevity, making it a cost-effective choice for rural women due to reusability. The microfibre pad is not just cheaper than the disposable pads, but also washes easily and dries quickly as compared to re-usable pads made from cotton (Chakwana and Nkiwane 2014).

An experimental research published in 2021 tested low-cost biodegradable materials (cotton terry cloth, linen, hemp cloth, bamboo wadding) for absorptivity in gelatine solution, potentially for menstrual hygiene products. Bamboo wadding exhibited the highest absorptivity index (7.86), surpassing other materials and a commercial pad. However, challenges related to complex bamboo extraction processes are discussed, despite its abundance in tropical low- and middle-income countries (Foster, Jasmin and Montgomery, 2021).

Menstrual hygiene is a crucial concern for women and girls in Bangladesh due to costly sanitary pads. A study by Shibly et al, tackles the issue by creating affordable napkin pads from natural fibers. Treated with Tulsi and Aloe Vera as natural antimicrobial agents, the pads become more cost-effective and safer for use. Research aimed to create an affordable and user-friendly sanitary napkin. Considering that the poor women not used to underwear, it used an adjustable waistband for attachment, avoiding adhesives. This hygienic, leak-proof alternative offers effective protection without undergarments during menstruation (Shibly *et al.*, 2019). A study in Southern Rajasthan, India, was designed to examine the menstrual products used by women and develop a new Uger Sanitary pad, and evaluated it against environmental, economic, social and health related parameters (Murthy, 2015).

Another paper reviews low-cost, eco-friendly, and reusable sanitary pads used by adolescent girls and women. Based on 21 literature reviews from 2010 to 2021, it explores sustainable menstrual hygiene solutions in rural areas of India, North America, Turkey, Nigeria, South Korea, and China. The review focuses on the role of advertising and marketing in creating awareness about menstrual hygiene management and promoting affordable reusable sanitary pads (Lather *et al.*, 2021).

A research project in Ethiopia, aimed at designing and developing reusable maxi pads for economically challenged individuals. The product features three layers: a bleached knitted cotton top layer for comfort and

absorption, a poly wadding middle layer for absorbency and washability, and a water-resistant fabric lower layer to prevent leakage. Surveys and technical tests supported its development, providing a cost-effective and hygienic solution for menstrual hygiene management (Tiku, Sufiyan and Chandra, 2022).

Bangladesh's textile industry generates clothing waste, so a sustainable solution proposes making sanitary pads from recycled cotton sourced from knitwear waste, offering a lightweight, affordable alternative. Pads use recycled cotton for absorption, polyethylene sheet as a barrier, and non-woven fabric as the top layer, addressing environmental concerns. Sanitary pads made from recycled cotton have comparable absorption capacity and retention ratios to market-available pads. The wicking value is higher for recycled cotton pads. They are cost-effective, with raw materials costing less than USD 0.1 or BDT 1 per pad (Uddin *et al.*, 2020). In a study conducted by Dobur et al, a reusable sanitary pad with wings replaces disposable pads. Knitted fabrics from polypropylene, polyester, and woven cotton are used for effectiveness and durability. Polypropylene's properties make it skin-friendly. Muslin fabrics' multilayer weave construction provides faster drying and increased absorption. The final design incorporates two layers of four-layer muslin fabric, suitable for heavy menstrual flow (Dobur *et al.*, 2022).

A study found that 88% of women in Muzaffarpur district adopted Jan Ausadhi Suvridha Sanitary Napkin (JASSN). Profession, income, and awareness of PMBJP influenced adoption. JASSN's affordability and ease of use supported rural women's menstrual hygiene, aligning with Swachha Bharat Abhiyan's objectives (Srivastava, Kumari and Lal, 2022).

### **Improvements in the properties of sustainable sanitary pads:**

An experimental research aimed to create an eco-friendly sanitary napkin with a multilayer structure using biodegradable materials. The top sheet combines needle-punched wool fiber and cotton non-woven fabric for dryness. Various core layer combinations with SAP (Super Absorbent Polymer) and cotton, bamboo, or a blend are tested. A biodegradable polyethylene plastic serves as the barrier layer. Herbal extracts (*Curcuma longa* and *Azadirachta indica*) act as antimicrobial agents (Barman, Katkar and Asagekar, 2017).

Another research aimed to develop an organic and



biodegradable sanitary napkin using banana fiber, cotton, neem, and oil cloth. The design ensures softness, antibacterial, and antifungal properties, reducing irritation and redness. Banana fiber is preferred for its absorbency and qualities over bamboo fiber. Neem provides protective antibacterial and antifungal benefits, preventing discomfort and itching. The layers are sewn together without adhesive (Banappagoudar, 2021).

A 2018 study develops an affordable, antimicrobial sanitary napkin using Flax spinning waste fiber as filler material. College girls' survey highlights comfort and texture as selection criteria. Neem plant extracts provide antimicrobial properties. Both tested napkin sizes have high Acceptability Index ratings (81.11% for regular, 81.55% for large), showing user acceptance (Babel, and Mishra, 2018).

### Conclusion:

The review paper covers various studies on sustainable menstrual hygiene management and environmentally friendly sanitary pads. It explores factors influencing menstrual health and hygiene, identifies sustainable alternatives, assesses low-cost and recyclable materials, and reviews initiatives to improve sustainable pad properties. The studies emphasize the need for user-friendly innovations, awareness, and education to promote eco-friendly choices and behavioral changes in menstrual practices.

The study explores sustainable alternatives for sanitary napkins. The study explores low-cost and reusable options for menstrual hygiene. The study emphasizes the need to promote sustainable menstrual practices through user-friendly innovations and awareness about alternative choices.

The review paper also notes the scope for research in the area of bio-engineered fibres in the development of fully sustainable sanitary pads. There is also a scope for focused research on the development of post-partum sanitary napkins.

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