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Original Article

# Sustainable alternatives for producing biodegradable Sanitary Napkins

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**ABSTRACT:** Sanitary Napkins ensue multiple implications on the agenda of Sustainable Development Goals. Comprising an estimated 0.13% of the total solid waste turnout of Bangladesh, sanitary napkins contribute little. Being a developing country —use of sanitary napkins in Bangladesh is comparatively low. With ensuing GDP growth, the use and disposal requirements will increase inevitably. All sanitary napkins consist polyethylene, polypropylene and superabsorbent polymer gels (SAP) making them environmental hazards. This study aims to review biodegradable polymers currently available that may produce sustainable alternatives to non-degrading components currently used. Lyocell™, Sodium carboxymethyle cellulose (Na-CMC), Acrylate grafted Banana fiber, Combination of Chitosan (CTS) and Silicon nanoparticles obtained from Rice husk ash (RHA), Crosslinked jute pulp (JP) with polybutylacrylate (PBA) and Sodium Silicate (SS), Starch Bioplastic, and Polylactic acid –have shown promising results as degradable biopolymers. Combining these compounds in a single product could solve the degradability issues associated with disposable sanitary napkins.

**Keywords:** Hygiene, Biodegradable, Disposable, Biopolymer

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## INTRODUCTION

Sanitary napkins are a major source of plastic pollution, which is greatly overlooked compared to other sources (i.e. plastic bottles, packaging). Disposable napkins are used by about one-tenth of adolescents (rural: 10%, urban: 21%) and one quarter of adult women (rural: 10%, urban: 33%) in Bangladesh[1]. Together they roughly consume 37000 tons of disposable sanitary products annually. Majority of this vast sanitary waste is either dumped in landfills and river banks, or is incinerated. In India the situation is equally grim. A study conducted by UNICEF in West Bengal concluded that 78% of the women interviewed disposed sanitary waste either by burial or by discarding near a water body[2]. In North America annual disposal of sanitary napkins in landfills reaches an estimate of 55000 tons. Although incineration is deemed the safest form of disposal, it requires extensive resources rendering the method counterproductive.

WHO recommends incinerating all health-related waste at temperatures over 800° C. Moreover plastic polymer products incinerated at lower temperatures release asphyxiants and irritant gases such as Dioxins and Furans. An assessment by Royal Institute of Technology, Stockholm concluded that, Low Density Polyethylene (LDPE) synthesis has the largest impact on global warming[3]. Sanitary napkins employ varying forms of LDPE in myriad forms. Through thermal or photochemical degradation, constituents of these products release Micro/Nano plastic particles in the oceans[4]. Consequently via algal and microbial uptake, these synthetic particles have a high probability of becoming incorporated into the food chain[5, 6]. The general design of sanitary napkins employs non-degradable materials in each component. Transitioning to degradable raw materials is the preferred path to reduce the overall impact of sanitary napkins. In this study current constituents of sanitary napkins along with their sustainable alternatives have been reviewed. Alternatives were selected on the basis of functional characteristics and efficacy.

## COMPONENT OVERVIEW

Low degradability and Non-recyclability of sanitary napkins is due to the compounds employed in the general design. A typical sanitary napkin employs up to seven components. Functional layer design has not undergone any noteworthy change since the first production in 1896[7]. Drastic improvement in napkin dimensions and absorption capability came with the incorporation of superabsorbent gel particles in the absorbent core[8]. Ordinarily a typical sanitary napkin is devised in to the following layers;

### Top sheet

Top sheets are water permeable layers designed to stay in contact with skin[8]. The functional purpose of this layer is to transfer fluids quickly to the layer beneath. High wicking ability is a mandatory trait for functional efficacy[9].

### Absorbent core

Function of this layer is to absorb and store fluids passed from the top sheet[10]. Once absorbed, fluid is essentially locked into the core to prevent spillage from applied pressure[11]. Absorbent compound may or may not be enclosed in a layer of cellulose fluff to facilitate speedy absorption[12]. Compounds employed in the core need to have a high rate of fluid retention.

### Bottom sheet

Bottom sheets function as a water impermeable barrier to ensure complete spillage prevention. Adhesives/winged appendages are provided with this layer for fastening purposes. Skin contact is negligible due to localization[10].

### Miscellaneous

Emollients on top layer and an additional acquisition layer above the absorbent core may be present depending on product class. Emollients are applied to protect skin from irritation[12]. Additional acquisition layers are provided to disperse fluids evenly onto absorbent core while preventing reflux[13].

## ENVIRONMENTAL IMPACT ASSESSMENT

Risk assessment and regulation of sanitary napkins varies between countries. Some countries may employ legal enforcement while others may depend on manufacturer's control[19]. Whichever the case, risk assessments are carried out with respect to human exposure only[7, 10]. There is a significant lack of research to establish environmental risk factors. Research on Polyethene and Polypropylene provides the only basis for the harmful effects of sanitary napkins –which is hardly adequate. Excerpts from reports on plastic pollution fail to address non-plastic based components in sanitary napkins and their environmental impact.

Biodegradation of LDPE has undergone a tremendous amount of research. However, the majority of these studies were conducted in in-vitro conditions – rendering the findings inconclusive with regard to disposal conditions in nature (i.e. landfills, aquatic systems). Biodegradability is highlighted in Table: 1.

General environmental impact of sanitary napkins is given below as associated with components.

### Superabsorbent polymers

Superabsorbent polymer exposure increases soil moisture, while soil bulk density is reduced. Exchangeable acids/ions present in SAPs may influence soil acidity and alkalinity, nutrient availability along with microbial activity[20].

### Polyethelene fibers and films

Accumulation of Polyethelene in soil results in reduced soil aeration, increased soil temperature and inhibits absorption of water and nutrients[22]. Due to its non-degradability Polyethene prevents root germination of plants and remediation of biomass into soil. LDPE disposal in marine ecosystem has notably affected 267 species globally, either by physical harm or by ingestion of micro/macro particles[5, 23].

### Polypropylene non-woven

Time extensive natural degradation of propylene releases volatile organic compounds (i.e. Propene, Dioxins). Air pollutants such as particulates, sulfur oxides, nitrogen oxides, and carbon monoxide are generated during polypropylene production[24]. Laboratory analysis of random samples has detected chromium, copper, lead, nickel, and zinc, which indirectly affects agriculture, forestry, and biodiversity by production[25].

## ALTERNATIVE CONSTITUENTS

This study aims to review currently available biopolymers as sanitary napkin components. Method of synthesis is highlighted with emphasis on biodegradability of these compounds. Each compound reviewed has an established application along with the potential for replacing one or more non-degradable components in current sanitary napkins. Alternatives according to associated layers and their laboratory synthesis are as follows:

### Top sheet

#### *Lyocell*

Cellulose fiber containing form of Rayon. Cellulose fibers are produced from bleached wood pulp. According to FTIR spectra fibers made from Lyocell contain crystalline cellulose II and amorphous cellulose[26]. Wood-pulp (collected from responsible remediation of forest output) is dissolved in a solution of heated N-methyl morpholine oxide (NMMO). The prepared solution is then extruded (spun) into fibres while excess solvent is extracted. The fibres pass through a washing process as the final step[27]. Lower mechanical strength is observed due to fibre-matrix adhesion after wetting while wicking and fluid transfer rates are comparable to polypropylene[28].

### Absorbent core

#### *Sodium carboxymethylcellulose*

The formation of superabsorbent polymer (NaCMC-g-PAA) uses NaCMC and polyacrylic acid/sodium acrylate as raw material. The process requires N,N'-methylenebisacrylamide (MBA) and $K_2S_2O_8$ (KPS) as a free radical initiator. NaCMC are treated to yield reactive NaCMC macroradicals. The macroradicals initiate monomer graft copolymerization (acrylic acid and sodium acrylate). MBA cross-linkers facilitate the formation of crosslinked NaCMC-g-PAA[29].

#### Acrylate grafted Banana fiber

A mixture of toluene/ethanol is used to extract banana pseudo-stem fiber (BP). Banana pseudo-stem based carboxymethyl cellulose (BPCMC) was produced by stirring cellulose with NaOH (40%) in isopropyl alcohol. BPCMC-g-poly (NaAc-co-AM) was prepared by free radical graft copolymerization of BPCMC with Sodium acrylate and acrylamide (NaAc-co-AM). Ammonium persulfate (APS) was used as initiator and MBA acts as crosslinker[30].

#### Crosslinked Jute pulp (JP) and Polybutylacrylate (PBA)

Jute pulp (JP) is prepared from harvested jute by an alkaline sulfite process[31]. The pulp is first soaked with appropriate quantities of Butyl acrylate (BA) monomer. Potassium persulfate (KPS), Histidine, CuSO4, and other solvents are added to the reaction vessel. KPS provides grafting equilibrium. Ice bath followed by addition of a small amount of hydroquinone (as quencher) is used to terminate polymerization reaction[32].

#### Combination of Chitosan acrylate and Silicon nanoparticles

Chitosan-graft-polyAA/RHA SAP was produced by mixing CTS-solution with AA. KPS generates free radicals on CTS surface. Later, a solution of acrylic acid, MBA and RHA (rice husk previously calcined) is added to yield final product[33].

### Bottom sheet

#### *Strach Bioplastic*

Starch acetate plastics are synthesized without the use of solvents. The process includes a low temperature, staged addition of catalyst mixture (methanesulfonic acid, concentrated sulfuric acid or a mixture of sulfuric and hydrochloric acid) along with an acetylation agent. Biodegradable plasticizer and other polymers maybe added according to function of product[34].

#### Polylactic acid

Synthesis is carried out in 3 steps: Polycondensation, obtainment of lactide and ring opening polymerization (ROP). Lactic Acid (LA) combined with Stannous octoate (used as catalyst). Polycondensation removes water from the LA yielding lactide. Lactide is distilled at 220 °C temperature and reduced pressure of 200 mmHg. Extracted lactide is then mixed with the catalyst to form PLA via ROP[35].

## DISCUSSION

Lyocell is one of the strongest contenders in reducing the use of polypropylene fibers in textiles. Grafting Sodium carboxymethyle cellulose, Banana fibres, Jute pulp and Rice husk on to polyacrylates yields a standard form of biodegradable superabsorbent that fulfils the necessary criteria of water absorption, water retention and reflux resistance from mechanical stress. Polylactic acid and Starch Bioplastics have already been proven to be equally water resistant to their petroleum derived counterparts. Combining these substances has the potential of give birth to safe, biodegradable alternatives for conscious consumers while also creating awareness in the general mass.

Currently available sanitary napkins are up to 90% plastic rendering them immune to degradation for as long as 800 years. Because these compounds persist in the environment –they provide a breeding ground for blood borne pathogens (i.e. Hepatitis B, HIV, Salmonella etc.). Bangladesh's waste management system depends largely on its informal barrage of waste collectors. Through sanitary napkins they are at immediate risk of severe infection of said pathogens which may develop to epidemic proportions[36]. Such an event is highly plausible due to the fact that Southeast Asian countries classify sanitary napkins under municipal solid waste instead of biomedical waste.

Analytics of biodegradable SAP given in Table: 2 provide a strong basis for applying them in commercial products. Components reviewed in this study have an established degree of biodegradability in in-vitro studies. Although laboratory synthesis has been completed, commercial production is only available for Starch Bioplastics. Extensive research is yet to be undertaken regarding industrial manufacturing methods. Industrialization of complete biodegradable products is a major milestone on the agenda of Sustainable Development Goals. As the world enters the age of renewable energy, reducing dependence on petroleum based products may prove to be a clear advantage for developing countries like Bangladesh.

Table 1. Constituent compounds, their chemical nature and biodegradability factors [8, 9, 14, 15, 16, 17, 18, 21].

| Functional layer | Compound | Chemical nature | Biodegradability | Organism |
|---|---|---|---|---|
| Top | Polypropylene fiber | Isotactic; Non oxidizing Acid, Alkaline and Organic solvent resistant | Organisms with known metabolic flexibility can degrade in specific conditions | Microaerophilic microbial community |
| Acquisition | Polypropylene/ Polyethylene nonwoven | Isotactic; Non oxidizing Acid, and Bleach resistant | Nondegradable in natural form. Specific microbes may facilitate | Microaerophilic microbial community |
| Core | Super absorbent Polymer gel (SAP) | Water insoluble, Capable of water retention | White-rot fungi and Soil microbes synergistically cooperate in degradation | *P. chrysosporiurn* |
| Bottom | Polyethylene/ Polypropylene film | Isotactic; Non oxidizing Acid, Alkaline and Organic solvent resistant | Reduce molecular weight, Time extensive erosion of surface. Complete degradation is absent. | *Aspergillus niger*, *Penicillium funiculosum*, & *Paecilomyces variotii* |

Table 2. Characteristic evaluation and mechanisms involved of SAP alternatives [29, 30, 31, 32, 35].

| Compound | Characteristics | Result | Mechanism |
|---|---|---|---|
| NaCMC-g-PAA | Swelling capacity | 544.95 $gg^{-1}$ | Enhanced hydrophilicity |
| BPCMC-g-poly (NaAc-co-AM) | Dye adsorption and recovery | 333.3 $mgg^{-1}$ | Electrostatic attraction between the surface of the absorbent and the cationic dye was reduced |
| CTS-g-polyAA/RHA | Water uptake ($W_{eq}$) capacity | $W_{eq}$ increased by 5% wt. | Increased pore size and hydrophilic interactions |
| JP-g-PBA/SS | Water absorbance | 358g$H_2O$/g | Increased porosity which facilitates water absorption |

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