Original Article

APPROACH FOR A BIODEGRADABLE POLYMER FOR SANITARY NAPKINS

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Abstract

The beginning of menstruation or periods is one of the most significant physiological changes happening among girls during the juvenile age. Despite being a physiological change, menstruation is surrounded by myths and misconceptions which prevent women from using menstrual products. In due time the growing concern about menstrual hygiene and menstrual products among the public as well as among the government has led to an increase in the use of menstrual pads or sanitary napkins which makes it easier to maintain menstrual hygiene with much comfort. However, along with its growing concern of disposal of these used sanitary napkins is an important matter of discussion due to non-biodegradable polymers used in sanitary napkins and decreasing landfills that were used for their disposal. To overcome these problems biodegradable polymers could be an alternative to replace non-biodegradable polymers used in sanitary napkins. Moreover use of natural polymers and biodegradable polymers could help in cost reduction and make them easily affordable. This review article is confined to the requirement for the use of biodegradable polymers and different types of biodegradable polymers that can be used for this purpose.

Keyword: Menstruation, Biodegradable, Super absorbent polymer, Polysaccharides, polyacrylates polymer.

Introduction

Menstruation is an important onset in the physiological and reproductive maturity of girls. Menstruation is part of girls' and women's lives and its normal cycle, but there are some cultural and religious beliefs or misconceptions regarding the menstruation period. **(Garg, Goyal and Gupta, 2012)** In Indian societies, there is a huge taboo regarding blood, menstruating girls, and menstrual hygiene. The requirement of material that can absorb blood and maintain clean menstrual management that can be changed and discarded in privacy is essential. The use of cloth for absorbing the menstrual flow was being the only option during menstruation and the use of soap and water for washing was required but it was insufficient to maintain the hygiene. Menstrual hygiene is important to reduce the increased risk of urinary tract infection, genital rashes, cervical cancer that increases further during menstrual periods. It is very surprising to know that still, 1% of women in India don't use anything to maintain their hygiene during their menstrual periods. **(Anand, Singh and Unisa, 2015)**

A Sanitary napkin has proved to be one of the important approaches for maintaining women's hygiene. Assuming that approximately 2.8 billion of the total population are women and half of the total women population age ranges from 15 to 50 if 100% of them uses sanitary napkins then the world market for sanitary napkin would be 252 billion napkins. But at present times, only less than 32% of women use sanitary napkins. The use of sanitary napkins in the Indian female population is very low at 10-11% of the total market, but this percentage in Europe and the United States is high as 73-92%. Various factors are responsible for less use of sanitary napkins in India

including lack of availability, affordability, lack of awareness, and very important lack of its disposal. **(Water-Aid, 2009)**

Despite such a less percentage of women using sanitary napkins, its disposal is a great matter of discussion due to the use of non-biodegradable polymers in their manufacturing. Non-biodegradable polymers used in sanitary napkins is one of the greatest problem associated with the disposal of a sanitary napkin. The non-biodegradable polymer has been leading to an increase in contamination and pollution. Some of the common materials used for the production of sanitary napkins include rayon (pulp), cotton, superabsorbent polymer (SAP), and back sheet supporting material. Dumping of sanitary napkins is becoming difficult today because of decreasing landfills and the cost of landfilling is increasing enormously. Other than the dumping of these sanitary napkins incineration is one of the other approaches for the disposal of the napkins, but that would lead to an increase in air pollution. **(Sathishkumar *et al.*, 2019)**

Sanitary napkins have replaced cotton cloths, which were often used in rural areas by women during the menstrual period. Although disposable cotton cloth was easy its use was not hygienic and it was replaced by disposable sanitary napkins. Along with the easy disposability of these napkins, their degradability is also important that could be possible by the use of biodegradable polymers.

Materials and layers used in sanitary napkins

Before advancing to the use of biodegradable or non-biodegradable polymer in manufacturing sanitary napkins it's important to understand the different layers of sanitary napkins. Sanitary napkins are divided into different layers according to the polymers used and their function in napkins. It is classified into a multilayered structure in which each layer has a specific function to perform. It mainly contains three layers top sheet, absorbent layer, and barrier sheet.

a) Top sheet: Top sheet generally act as a binding between the inner layers of sanitary napkins and the outer environment. These are designed in a way to quickly transfer the fluid from the top layer to the secondary absorbent layers of napkins. They generally contain hydrophilic absorbent fiber that allows the fluid to get absorbed without getting leaked out and the thermoplastic fiber present in them helps to prevent collapsing to this due to capillary force. Commercially available sanitary napkins generally use polypropylene fiber for acting as top sheets. **(Agbaku *et al.*, 2020)**

b) Absorbent layer: polymers used in this layer are designed to absorb and retain the fluid to prevent it from leaking. An absorbent layer is present in between the top sheet and barrier sheet. The super absorbent polymer that has high absorbing and swelling properties is generally used in this layer. SAP used in commercial napkins is completely non-biodegradable. They can generally remain intact in the environment after disposal for over years which can lead to increased contamination due to the absorbed menstrual fluid by the layer. Compared to all other layers of napkin absorbent layer largest ratio of polymers**. (Woeller and Hochwalt, 2015)**

c) Barrier sheet: Barrier sheet is generally composed of impermeable pigment polyethylene film that contains an adhesive layer, helps sanitary napkins to stick properly to the undergarment, and prevent slippage. This barrier sheet or back sheet functions in preventing the leakage of fluid from the sanitary absorbent layer. Polyethylene film used in barrier sheets is completely non-degradable for years thus requires a biodegradable alternative for this. Some of the modern scented napkins contain a small amount of perfume in between the barrier sheet and undersurface of the absorbent core. **(Rosinskaya and Weinberg, 2002)**

Superabsorbent Polymer (SAP)

Superabsorbent polymers (SAPs) are loosely bound three-dimensional hydrophilic crosslinked networks, they can swell, absorb and retain a huge amount of liquid. The three-dimensional structure of SAPs enables the polymer to keep the structure intact while holding the liquid and remain insoluble in the liquid. These properties of SAPs

make them suitable for use in many hygienic and agricultural products. The capacity of absorption of liquid depends on the degree of crosslinking of the polymer as well as the functional group present (-OH, $-SO_3H$, $-NH_2$). SAPs employed in commercial products can hold liquid up to a hundred times more than its weight. **(Kabiri and Zohuriaan-Mehr, 2003)** SAPs are commonly employed in personal care products, especially in the absorbent core of sanitary napkins. SAPs have the property of forming a gel when they come in contact with water and absorb them, this property help in preventing leakage from the surface of sanitary napkins, thus providing complete dryness to the consumer for a longer period. Nearly 900,000 tonnes of SAPs are produced annually and 90% of the total SAPs produced are utilized in personal care products and sanitary napkins.

Regulation of Sanitary Napkins:

Regulations for the manufacturing and sale of sanitary napkins differ from country to country. In some countries it is governed by legal enforcement on the other hand in others it comes under voluntary manufacturers' regulation. Sanitary napkins are classified as Class I medical devices as per USFDA that leads to manufacturing controls and consumer complaint management by USFDA. **(Woeller and Hochwalt, 2015)** In Japan, the manufacturing and sale of sanitary napkins are regulated by Pharmaceutical and medical devices agencies. Whereas in European Union, sanitary napkins are classified under consumer product regulations thus providing their manufacturing and sale easier. Various guidelines are issued by FDA for the regulation of sanitary napkins such as 510(K) premarket submission guidelines to regulate any sort of adverse tissue reaction to be identified that may occur from menstrual pads and voluntary biochemical testing is recommended to the manufacturers following ISO-10993 (Biological Evaluation of Medical Devices Part-1: Evaluation and Testing).

Safety and Hygiene of sanitary napkins in china are regulated under GB 15979-2002: Hygienic Standard for Disposable Sanitary Products, categorized under mandatory regulation. There are also some non-mandatory regulations (GB/T 8939-2008) for the regulation of sanitary napkins.

Challenges in waste disposal from the sanitary napkins

Many nations across the globe face the major challenge in proper disposal of the waste generated due to sanitary napkins as they still lack in adequate system in place for propoer disposal of the used sanitary product. Due to the lack of menstrual management practises worldwide, the majority of women dispose of their sanitary pads and other menstrual products in domestic solid waste or garbage cans, which eventually become a part of solid wastes (Ashley *et al.*, 2005). The majority of countries have developed techniques to manage their faecal and urinary wastes. In countries like India, where people lack in proper facilities for proper health hygiene, women undergoing menstruation have to face lots of challenges in waste disposal of menstrual products. Modern disposable menstrual products are utilised in metropolitan areas, where they are disposed of by flushing in toilets, discarding in trash cans, or using solid waste management (Wang and Wang, 2010).

Most women flush menstruation products down the toilets and throw them in household trash without thinking about the potential choking hazard. Therefore, there should be a need to inform and educate people about the health risks and environmental pollution linked to incorrect sanitary napkin disposal. Utilizing contemporary methods like incineration can aid in waste reduction. The usage of reusable sanitary items should be emphasised through awareness-raising efforts (Wang and Wang, 2010). Depending on the goods they used, the facilities, the period, the area, and the social beliefs, different women used various disposal techniques. 40% of women dispose of their sanitary waste in trash cans, 18% in rivers or by the side of the road, 18% bury it, 15% burn it, and 9% flush it down the toilet. In India, a typical woman discards over 150 kg of nonbiodegradable trash annually. As lifestyles and sanitation standards change and women become more conscious of the value of their health, the usage of sanitary napkins rises, creating problems for the sewerage system, landfills, and water bodies.

Effect of Non-biodegradable polymers of sanitary napkins on environment

Cross-linked and partially neutralized sodium polyacrylates are most commercially used due to their affordable price and superior absorbing capacity. But these SAPs have a high molecular weight and are non-biodegradable. Disposal of such sanitary napkins with non-degradable polymer is becoming a larger problem. A recent study found that on average menstruating women use 240 sanitary napkins annually during their menstruation period. According to the study, a woman disposes of 10000-12000 menstrual products in her complete lifetime. These disposed of sanitary napkins take around 500- 800 years to degrade, such open environment disposal leads to increase contamination and increasing pollution.

Problems associated with the non-biodegradable and poor antimicrobial properties of these sanitary napkins and SAPs have made the researcher replace the SAPs with greener alternatives and focus on the biodegradable super absorbent product. **(Sathishkumar *et al.,* 2019)(Arugula *et al.,* 2017)** In a survey it was found that a country like Malaysia alone produces 2.4 billion pieces of sanitary waste annually, which sums to around 2400 tonnes per year of waste. Disposal of this sanitary waste or dumping in landfills has given rise to another negative impact of running out of land for the landfills. Most commercially used SAPs for the manufacturing of sanitary napkins are composed of polyacrylates polymers that possess toxicity and carcinogenicity properties. A biodegradable alternative would help to reduce the problems associated with the non-biodegradable SAPs as well as it could give a better way of disposal for the sanitary waste that does not require landfills. Polysaccharide and polypeptide-based SAPs give a biodegradable, biocompatible, renewable, and non-toxic alternative to these non-biodegradable SAPs.

The huge amount of disposal of the non-biodegradability synthetic sanitary napkin and SAPs into the landfill has drawn global attention to replacing the SAPs with greener alternatives. In Malaysia alone, 2.4 billion pieces of sanitary waste were produced annually, which is equivalent to 2400 tonnes a year. This non-biodegradable waste also poses a negative impact on the running out of land for the landfill in Malaysia. Substitution of using biodegradable SAPs will help to ease this problem as the SAPs can decompose and do not need to be sent to landfills for disposal. At the same time, the toxicity and carcinogenicity of residual monomers in polyacrylates-based SAPs also urge manufacturers to invest in a safer and more environmentally friendly SAP. SAPs based on renewable resource materials, especially polysaccharide-based and polypeptide-based SAPs, draw attention due to their biodegradability, biocompatibility, renewability and, non-toxicity. **(Peng *et al.,* 2021)**

Effect of sanitary napkins on women health

Along with non-biodegradable polymers as SAP and backing layer, commonly marketed sanitary napkins contain volatile organic compounds that function as a fragrance in the napkins. These fragrances are present in between the SAP layer and impermeable back sheet along with adhesive. Commonly used volatile organic compound (VOC) constitutes of styrene, chloromethane, chloroethane, acetone which are responsive to carcinogenic activities. **(Wendee, 2014)** Other than this methyl dibromo glutaronitrile (MDBGN) which is commonly used as an adhesive layer in sanitary napkins are found to be a causative agents of dermatitis. **(Williams *et al.,* 2007)** Normal reproductive functions were found to be affected because of the toxicity of VOCs been used in the sanitary napkins. Data from the Swedish chemical agency reports that the sanitary napkins been marketed popularly contained super adsorbent polymer (sodium polycarbonate) along with their metabolites such as glycerol propocytriacrylate, triallyl amine, divinyl toluene, polyethylene glycol monoallyl. The presence of these metabolite products proves to be harmful to women's health. **(Woo *et al.,* 2019)**

Biodegradable polymers:

Various types of biodegradable polymers that can be obtained from various resources like animal feedstocks and plant sources have the potential ability to act as SAP as well as other layers of sanitary napkins. The abilities of such polymers can be much enhanced by blending or processing them with some other ingredients like plasticizers

and additives. Despite all the abilities they would be biodegradable in nature which would make them easy to dispose of.

One such example of a biodegradable polymer that can be used in sanitary napkins is a composite film containing a combination of hydrocolloid and lipids. Hydrocolloids generally lack proper moisture barrier property of their own. But its moisture barrier property can be enhanced in combination with lipids. Such composite films are made out of a mixture of these types of biomolecule along with other ingredients. The use of biodegradable plasticizers or plasticizers from plant sources can be used for reducing the brittleness of the polymers making them suitable for use in the manufacturing of sanitary napkins. One such method of using a wax coating of fruits by dipping methods is one of the age-old methods for the use of a plasticizer.

The concept for use of biodegradable polymers is being rapidly increasing all over the world. Biodegradable polymers are considered an environmental waste management system. The two main reasons for the increasing interest in the use of biodegradable polymers are growing problems for waste disposal due to decreasing landfills as well as damage caused to the environment by the non-biodegradable polymers. Many researchers have come up with the method and polymers that can replace the use of non-biodegradable polymer few such polymers are given in table 1.

Table 1: Various biodegradable polymers for use in sanitary napkins

Sl. No	Biodegradable polymer	Source and its derivative	Function	Absorptivity	Biodegradability	Reference
1	Chia flour	Chia Seeds (*Salvia hispanica* L)	SAP	2.077 g/g	Soil burial test (1-3 month for 100% Biodegradability	(Peng, Sethu and Selvarajoo, 2021)
2	Mimosa pudica hydrogel	*Mimosa pudica* L	SAP	5.225 g/g	Soil burial test (1-3 months for 100% Biodegradability)	(Peng, Sethu and Selvarajoo, 2021)
3	Heat-treated high-molecular-weight CMC sodium salt	-	SAP	27g/g	-	(Sun and Data, no date)
4	Heat-treated dry CMC and cross-linked with polyvalent metal salts and chitosan salts.	-	SAP	50g/g	-	(Mui, 1996)
5	chitosan–heparin PEC	shellfish waste	SAP	15 g/g	-	(Qin, 1997)
6	crosslinked starch-graft-poly(acrylic acid)	starch and acrylic acid (AA)	SAP	1077 g/g of Distilled water and 61 g/g of 0.9% of NaCl	-	(Li, Zhang and Wang, 2007)

7	Polyelectrolyte hydrogels	CMCNa and HEC using (DVS)	Super absorbent cellulose derivatives	-	-	(Sannino *et al.*, 2003)
8	nano-hybrid composite (HEC-g-PAA/diatomite)	Graft polymerization of acrylic acid and HEC in presence of N, N'-methylene bisacrylamide (MBA)	SAP	1,174.85 g/g distilled H2O and 99.55 g/g in 0.9 % NaCl	-	(Mukerabigwi *et al.*, 2016)
9	Waste cotton fluffs, Neem, and orange peel extract	Cotton fluffs as SAP and neem-orange peel as capping agent during copper-based nanocolorant synthesis	SAP and capping agent	Commercial SAP absorbs 300 times the weight of water while Cotton SAP absorbs 157% of water.	Solution-based degradation, cotton showed 50% degradation in 30 days.	(Sathishkumar *et al.*, 2019)
10	Sodium CMC and starch	Cross-linking of NaCMC and starch with a combination of sodium trimetaphosphate and aluminum sulfate	SAP	83.5 ± 2.51 g/g of Saline water under 50g of compressive load	Soil degradation study showed 24.33 ± 6.94 % of weight loss in a six-week study	(G *et al.*, 2020)
11	carboxymethyl cellulose (CMC)	(CMC) and then cross-linked with epichlorohydrin (ECH)	SAP	725 g/g of distilled water and 118g/g of 0.9% NaCl water	-	(Alam, Islam and Christopher, 2019)
12	Wool fiber, non-woven cotton, and bamboo fiber	Wool fiber needle punched on non-woven cotton for the top sheet, cotton-bamboo-blend of cotton/bamboo (50/50) as SAP, biodegradable polyethylene as a barrier sheet	Top layer SAP and Barrier layer	43.5g/g of artificial blood for cotton core, 25g/g of artificial blood for bamboo, and cotton/bamboo blend core	-	(Barman, Katkar and Asagekar, 2017)

13	Guar gum-g-poly(sodium acrylate)	Graft copolymerization of natural guar gum with partially neutralized acrylic acid	Super absorbent hydrogel	1107 g/g in distilled water and 88 g·g–1 in 0.9 wt% NaCl solution	-	(Wang and Wang, 2010)
14	Sansevieria trifasciata plant fibres	Extracted fiber treated with Sodium hydroxide solution with ratio 1:200 and bleached with different conc. of hydrogen peroxide	SAP	5g/g of water	-	(M, 2021)

*PEC- Polyelectrolyte complexes (PEC), CMCNa- carboxymethylcellulose sodium salt, HEC- hydroxyethylcellulose, DVS- divinyl sulphone, HEC- Hydroxyethylcellulose, g-PAA- graft polymerization of acrylic acid

Conclusion:

The increasing number of non-biodegradable polymers and shortage of landfill space has increased the concern over the dumping, disposal, and handling of this waste. This concern has made us move towards the use of biodegradable polymers. In order to replace non-biodegradable polymers with biodegradable polymers, it needs to have all the desired properties along with retaining its biodegradable nature. The present biodegradable polymer could not meet the desired properties of polymers alone thus needs modification in form of chemically or physically along with some other polymers or ingredients.

Another important point of concern is the cost reduction in making these biodegradable polymers meet the desired properties that suites our requirements. The blending of existing biodegradable polymer with different materials can reduce the cost and make the polymer suitable for a specific application. Encouragement of natural resource development and agriculture could prove to be a key factor in increasing the use of biodegradable polymers. The government could encourage the use of such polymers and reduce the use of non-biodegradable polymers by reduction in tax levied on the use and manufacturing of biodegradable polymers.

Biocomposite fiber possessing a more complex structure has been a challenge in the use of these polymers for various uses, thus more enhanced studies on properties of biocomposite fiber are required to be established to increase its proper use. Training must have priority to accelerate the acceptance of biocomposite for various applications.

Conflict of Interest

Authors have none to declare.

Author contribution

All the authors have equal contributions in the completion of the article, starting from the preparation of a framework for the article, literature survey, a compilation of data, and corrections.

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