

A Generative AI Paradigm for a Global Crisis: Redesigning the Sanitary Pad Polymer Lifecycle for Environmental and Public Health in India

Ritam Rajak¹, Eshani Sadhukhan^{2,*}, Tanmoy Majumder³, Piyali Roy Chowdhury⁴, Indrajit Ghosal⁵, Nilanjan Ray⁶, Sudip Basu⁷

Abstract

The sale of disposable sanitary pads, most of which contain non-biodegradable polymers, especially polyethylene (PE), polypropylene (PP) and superabsorbent polyacrylates (SAPs), has led to a souring environmental and population health crisis, especially in India. A linear economic approach of take-make-dispose has resulted in the exponential growth of polymer waste that fully blocks drains, leads to microplastic pollution, and overloads insufficient waste management facilities. Traditional polymers are designed to be permanent their carbon-carbon (C-C) bond backbones and cross-linked molecular structures are not degraded by enzymes or microbes and are almost untenable to recycle and dispose safely. The current study does not address just a problem of waste management but the failure of the material and product design right which is the argument of this article. The article suggests a new Generative Artificial Intelligence (AI) paradigm to recycle the whole lifecycle of the sanitary pad by designing material innovation and product circularity with data, and adaptive waste logistics. Using the generative power of AI, the framework will create biodegradable biopolymers, including polylactic acid (PLA), polyhydroxyalkanoates (PHAs), and citric-acid-based superabsorbent polymers and design pads, among others, designed to be disassembled and produced with low impact. Through that, a linear pollution issue can be made to evolve into a regenerative materials economy that is circular. The research provides a policy and industrial roadmap to integrate the concept of generative AI into sustainable development of sanitary products, and integrating the duty to serve the people together with the duty to serve the environment.

*Author for Correspondence

Eshani Sadhukhan

¹Assistant Professor, Department of Computer Science and Engineering (AIML), Moodlakatte Institute of Technology, Kundapura, Karnataka, India

²Assistant Professor, Department of Management, Brainware University, Barasat, West Bengal, India

³Assistant Professor, Faculty of Management, JIS University, West Bengal, India

⁴Assistant Professor, School of Business and Management, CHRIST University, Bangalore, Karnataka, India

⁵Associate Professor, Department of Management, Brainware University, Barasat, West Bengal, India

⁶Associate Professor, Faculty of Management, JIS University, JIS University, Kolkata, India

⁷Assistant Professor, Department of Management Studies, Asansol Engineering College, West Bengal, India

Received Date: 10 October 2025

Accepted Date: 03 November 2025

Published Date: 13 January 2026

Citation Ritam Rajak, Eshani Sadhukhan, Tanmoy Majumder, Piyali Roy Chowdhury, Indrajit Ghosal, Nilanjan Ray, Sudip Basu. A Generative AI Paradigm for a Global Crisis: Redesigning the Sanitary Pad Polymer Lifecycle for Environmental and Public Health in India. Journal of Polymer & Composites. 2026; 14(Special Issue 1): S1570–S1591p.

Keywords: Generative Artificial Intelligence, Circular Economy, Sanitary Pad Waste, Polymer Composites, Waste Management, Public Health, Sustainable Materials.

INTRODUCTION: THE PERSISTENT POLYMER AND THE DISPOSABLE IMPERATIVE

The twenty first and the twentieth centuries have been typified by a convenience paradigm which has established a global economy which assumes single-use products. The disposable sanitary pad, in this regard has been the corner stone of the new feminine hygiene which are in use by billions of individuals around the world [1]. Its mass application is a huge leap towards more comfort and personal freedom, yet has also created an environmental issue of scale never encountered before. This section is going to raise

the aspects of the world of this problem, condemn the simple industrial model that perpetuates the problem and establish the material science foundation of the problem [2]. Finally, it will contain the main thesis of the current paper: the proposal of the new paradigm, which will be fueled by the generative artificial intelligence, to radically redesign the lifecycle of these inseparable items.

Situating the Crisis: The Global Scale of Single-Use Hygiene Waste

Disposable sanitary pads are used universally and the rates of consumption are rising both in the developed and developing nations [3]. This has contributed to millions of tons of non-biodegradable waste in the form of polymer that is produced every year [4]. This waste stream, however, is unique in structure and also has a close link to human settlements, but is often overshadowed by the larger scale type of municipal solid waste, with its specific impact on the environment and human health not always considered at a systemic level. This indestructible waste material combined with sheer volume is a formidable challenge to any waste management facility in the world, to the hi-tech landfill of the Global North as well as the overstretched and often informal infrastructures of the Global South [5]. Such a scale of the problem requires a re-thinking beyond recycling, and developing a unified vision of the complete product life cycle.

The Prevailing Linear Paradigm: A Critique of "Take-Make-Dispose"

The disposable sanitary pad is a typical product of the linear economy model of a paradigm based on the take-make-dispose cycle [6]. The model starts with the extraction of raw materials, mainly fossil fuels, to be used in the production of polymer and wood to be used as cellulose pulp. These resources are then turned into a product with very short functional life which could be a few hours. Once this short-term use is finished, the product is disposed of, with final destination being a landfill or incinerator, or, most commonly, the open environment. This simple straight line direction is in effect unsustainable; it consumes limited natural resources at the point of origin, and leaves a trail of irreversible pollution at the end [7]. There is no inherent process of recovering the materials or having a value restored and the planet is seen as an endless source and an endless sink. This paper argues that any solution of any significance, must, therefore, be a direct mailing of this long held and very imperfect paradigm.

The Material Foundation of the Problem: An Introduction to Polymer Composites

The problem of disposal centers on a very critical issue of material science. Sanitary pad is not a simple product, but a complex of synthetic polymers and natural fibers, the selection of which are determined with respect to a certain performance property [8]. Polyolefins (polyethylene and polypropylene) are the key ingredients that provide high levels of durability as protective, waterproof barriers, and Super Absorbent Polymers (SAPs) that provide an incredible potential of fluid storage [9]. They are made to be permanent by virtue of the chemical properties of these materials. Their molecule structures are very hard to the enzymatic degradation of nature. This inbuilt resistance, which so far has been celebrated as a virtue during the lifespan of use of the product, proves to be its worst characteristic during its end-of-life [10]. These synthetic polymers are tightly entwined with a cellulose-based structure to create an extremely difficult to break down composite, and in that case, it is not compatible with the existing recycling infrastructure. It is the problem of material design [11], therefore, that the sanitary pads waste.

The Proposed Paradigm: A Thesis for Generative Redesign

To resolve this complex crisis, this paper is based on a key thesis which challenges the principles of the present-day disposable model. It claims a gradual progress in waste control is not enough to solve a problem that goes so deep in the material science and industrial design [12]. True solution needs a paradigm shift of reactive posture of dealing with waste to proactive one of designing waste out of the system. The paper is based on the assumption that the facilitating factor behind such a transition is Generative Artificial Intelligence (AI). The given paradigm does not imply the implementation of analytic AI, to improve a broken mechanism, but the implementation of generative AI as an engine of

the creative process, of designing a new mechanism, molecular to molecular. Thus, the architectural concept of an AI-driven framework capable of autonomously search an enormous solution space to design new, biodegradable polymers; simulating the lifecycle effect of novel product designs before they are actually produced; and planning adaptive information management systems to achieve real material circularity are introduced in this work. The main thesis is that not better disposal, but smarter design, generative, is the key to the solution of this dangerous pollution issue that persists.

THE MATERIAL SCIENCE IMPASSE: POLYMERS ENGINEERED FOR PERMANENCE

The modern disposable hygienic pad is a material science discovery to be comfortable, safe, and cost-effective. Nevertheless, it is also the same material composition that is further developed into making it useful that introduces an entire dilemma when considering the end-of-life management. The product life cycle of disposable sanitary pads is always linear due the polymers that are designed to make up these pads, and that cannot be broken down through biological and chemical means [10]. This section disintegrates the composite structure of the product, examines the chemical causes of its endurance, and explains why mechanical as well as chemical recycling are also not viable alternatives.

Deconstructing the Modern Sanitary Pad: An Anatomy of a Composite

The end-of-life challenge cannot be understood unless one first breaks down the complex, multi-layered architecture of the product. It is not a single homogenous structure but rather a multi-layered structure with a specific physical or chemical role of each layer [12]. This duality is the key to its failure in any existing circular economy model. In order to understand the end-of-life issue, it is necessary to break down the multi-layered structure of the product, a composite structure, the material composition of which has been widely investigated in the framework of performance-based research (Ibikunle et al., 2015) [13]. This complex layered aspect can be identified by observing a cross-sectional perspective as shown in the schematic in Figure 1.

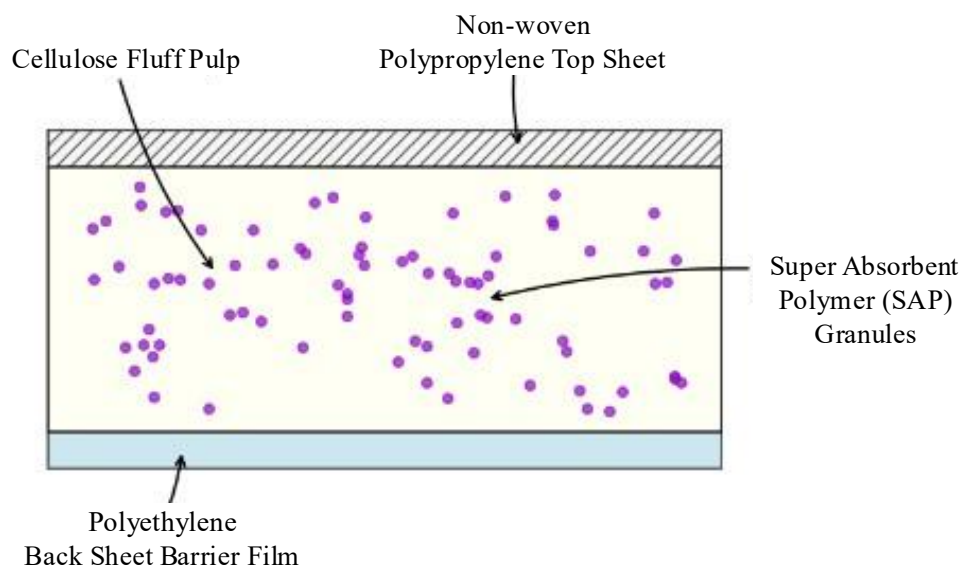


Figure 1. The layered composite structure of a disposable sanitary pad.

Source: https://www.researchgate.net/publication/284168604_PERFORMANCE_CHARACTERISTICS_OF_LOCAL_AND_IMPORTED_SANITARY_PADS

The Polyolefin Layers: Hydrophobic Barriers of Polyethylene and Polypropylene

Sanitary pads have both the outer and see-through layers that are made of mostly polyethylene (PE) and polypropylene (PP) which are representatives of the polyolefin family of thermoplastics [14]. Its upper nonwoven sheet (typically PP) serves the purpose of wicking a fluid off the skin, but keeping skin dry to feel dry to the touch [9]. The bottom film is PE which acts as an impermeable layer that ensures that it does not leak and preserves structural integrity upon usage [15].

These polyolefins have extended carbon-carbon (C-C) bond backbones, which give them strength, flexibility, and moisture and heat resistance [16]. But, it is an inherent contradiction of this chemical structure that generates an intrinsic resistance to degradation. The C-C bonds of these compounds are non-polar and chemically stable forms of bonds which lack reactive sites that can be attacked by microbes or enzymes and these materials are therefore non-biodegradable under the circumstances of the environment [17]. The indiscriminate disposal of these pads in India, either by open dumping or open burning leads to contamination over the long term of the soil and air. PE and PP also give off toxic gases like dioxins and furans when burned, whereas in landfills they last hundreds of years before broken down into tiny microplastics [11].

This polymeric persistence poses a matter of significant environmental due to the fact that India does not have a large scale plastic segregation and recycling facilities of sanitary waste. The results of this are that polyolefin layers end up in the municipal dumps and open environments, which become impermeable to soil and can create blockages in drains, thereby worsening the monsoon floods [18].

The Absorbent Core: Cellulose and Super Absorbent Polymers (SAPs)

The functional centre contained in the sanitary pad is the absorbent core which is a combination of two important materials, namely, natural cellulose pulp and synthetic super absorbent polymers (SAPs) [3]. The cellulose which is a by-product of wood pulp acts as capillary wicking and SAPs are usually cross linked sodium polyacrylates-absorb and hold fluid many hundreds of times its own weight [7].

The cross-linked molecular structure of the SAP does not permit dissolution or re-wetting, which is pleasant to the user but troublesome to environmental sustainability [19]. These networks consist of sufficient carbon-based chains and carboxylate groups, which have been ionically cross-linked in order to create a hydrogel structure, which is not susceptible to enzymatic degradation as well as hydrolysis [20]. This leads to the fact that upon disposal, the core fails to decompose naturally but instead remains as an inert, gel-like remains in landfills or soil [21].

Moreover, cellulose (biodegradable) and SAPs (non-biodegradable) form a heterogeneous compound which is difficult to break down through recycling or composting plants [20]. In India, it has resulted in the formation of untreated absorbent wastes in such open garbage dumps and waterways, which also leads to the generation of microplastic and improves the toxicity of leachates [18].

The Chemical Basis of Persistence: Recalcitrance to Biodegradation

The extreme durability of sanitary-pad polymers originates from their molecular architecture and physicochemical properties rather than from any limitation of the disposal environment. Polymers made of carbon-carbon (C-C), bond backbones, are highly stable, non-polar, and hydrophobic polyethylene (PE) and polypropylene (PP) long-chain hydrocarbon polymers [22]. The inactive presence of any of the hydrogen elements like oxygen, nitrogen or sulfur in these chains removes any reactive functional groups-esters, amides, glycosidic bonds- that are typically found by microorganisms and broken down by them during biodegradation [7]. Consequently, naturally occurring enzymes are unable to adsorb or catalyse the bond scission in these synthetic polymers.

The water resistance of PE and PP ensures that water cannot get into the polymer matrix which further limits microbial growth and hydrolytic degradation. This resistance is further improved by their semi-crystalline structure: crystalline domains containing tightly packed chains are very impervious to oxygen and water, and amorphous areas though a little more permeable, compose a small fraction of the structure. This geometrical property with large molecular weight results in very low oxygen and water diffusion coefficients, which practically prevent oxidative or hydrolytic cleavage in environmental conditions [9].

Sodium polyacrylate-based superabsorbent polymers (SAPs) applied to the absorbent core have a different, yet equally effective resistance to persistence, however. The SAP network is a polyacrylate

polymer cross-linked via covalent or ionic bridges and form three-dimensional hydrogel and can retain vast amounts of water without dissolving into it [12]. After being hydrated the polymer chains swell but chemically complex still; the cross links stabilize the chains, the carboxylate groups neutralized by the sodium ions minimize the chances of microbial attack [23]. These gels can remain structurally stable over longer durations even in composting or anaerobic-digestion conditions which dry into microplastic pieces, which remain in soils over time [2].

Cases Photodegradation Photodegradation can cause slight surface oxidation of PE and PP in intense exposure to ultraviolet (UV) photons, resulting in chain scission and the generation of low-molecular-weight oxidized species [3]. Thermo-oxidation Thermo-oxidation can cause shallow surface oxidation of PE and PP during extreme exposure to ultraviolet (UV) photon, which causes chain scission and formation of low-molecular-weight oxidists [13]. These processes are however very slow and instead of fully converting the material to the mineral forms of carbon dioxide and water, they result in the formation of secondary microplastics. The resulting micro- and nano-sized particles have an even greater surface-to-volume ratio, and thus allow chemical absorption of pollutants and trophic transfer in the ecosystems [14].

Together, these chemical, structural and environmental conditions are reasons why sanitary-pad polymers are recalcitrants to biodegradation. Dominating pictures of C-C backbones, hydrophobicity, crystallinity, and crosslinking mechanisms create synergies to resist biological and chemical degradation. This scientific foundation is relevant in the creation of next-generation materials with engineered weak links like ester or amide groups which can be broken by microorganisms but do not affect the performance of the product

The Failure of Circularity: Why Mechanical and Chemical Recycling Fall Short

The concept of circularity is based on the concept of reutilizing the materials in the production cycle once they are used. Nevertheless, both mechanical and chemical recycling are inefficient in the presence of inherent material intricacy and pollution found in the case of disposable sanitary pads [24]. Polyolefins, cellulose, and superabsorbent polymers are structurally integrated to avoid the segregation of the materials, whereas the availability of biological waste qualifies used pads as biomedical waste according to the Indian regulations, and there are no feasible ways to recycle them through conventional methods [13].

Challenges of Material Contamination and Separation

Mechanical recycling is the reuse of homogeneous plastic streams of waste by collecting, cleaning, processing it by shredding and then remoulded. Sanitary pads are, however, made of a heterogeneous polyethylene (PE), polypropylene (PP), cellulose and sodium polyacrylate-based superabsorbent polymers (SAPs) [25]. Mechanical separation of these layers is done by complex delamination technology, which is technologically and financially impractical on the large scale.

The used sanitary pads in India are usually mixed with their general domestic waste as segregation at the source is minimal. The biological contamination in addition to rest of moisture results in growth of microbes and odour thus making the material unsuitable to standard mechanical recycling system. Mechanical reuse of such trash has proven to have low productivity, quality of the recycle, and the leakage of volatile organic compounds during melting. The issue is further complicated by the absence of specific hygienic recycling facilities whereby open dumping or improvised incineration becomes the concession to the lack of alternatives [15].

Economic and Energetic Non-Viability of Current Technologies

Pyrolysis, gasification and solvolysis are chemical recycling processes that convert the plastic waste into monomers, fuels or chemical feedstocks. Theoretically, such technologies would reclaim material value on used sanitary pads but practically their use is not possible. High moisture content and combined

polymer compositions contained in the absorbent layers of sanitary pads disrupt thermal conversion efficiency [26]. Activities digressing to the pre-treatment, namely drying, sterilization, and segregation, consume a lot of energy and, hence, discard any sustainability benefits.

Moreover, the polyolefin-based materials (PE, PP) pyrolysis are characterized by an unstable structure of the hydrocarbon gases and oils obtained, whereas the rest of the SAPs are substances which can be converted to acrylic acid derivatives, thereby contaminating the product stream. Although gasification can be done with mixed waste, it emits dangerous gases when the input feed undergoes a chlorine- (or other nitrogen-containing) additive materials in some pad formulations [27].

In India, the industry scale pyrolysis plants are rather scarce, and the standardization of waste preprocessing is missing, which limits the feasibility of these technologies. As a result, there has been an underdeveloped and harmful to the environment recycling of polymers used in sanitary-pads by chemical processes [28].

The impediments of the technical and the logistical constraints of both mechanical and chemical recycling drive home the material science stalemate that the hygiene industry faces. Sanitary Pads have been designed to be efficiency in one use instead of recoverability in material and their chemical stability is in direct contrast to the ideas of a circular economy. The insufficient separation of waste, absence of treatment facilities and a highly energy-consuming recycling process of these products render these products practically inefficient in the Indian waste management system [29]. To end this shortcoming would require a radical redesigning of material via Generative Artificial Intelligence (AI)-driven biopolymer discovery, such that future sanitary products are compatible with performance requirements and ecological necessity.

THE ENVIRONMENTAL CASCADE: A CASE STUDY OF SYSTEMIC FAILURE IN INDIA

Although this deadlock in the material science is universal, its evolution in a critical environmental crisis is context dependent. This creates an ever-expanding, and yet very invisible, landfill burden in countries with well-developed and closed waste management systems. In India, however, a nexus of infrastructural deficiencies, dense population and compound conditions of social factors conspire to make this standstill a visible catastrophic cascade for the environment. The sanitary pad is a product with the intention to be inconspicuous but which rather becomes a conspicuous harmful form of pollution and a manifestation of system failure at the level of product design, at the level of infrastructures and at the level of social practice.

Quantifying the Burden: Waste Generation Statistics in the Indian Context

The issue of sanitary-pad waste in India has become a big environmental and human-health issue because of the speedy urbanisation process, increase in hygienic awareness, and poor and unsound waste-management infrastructure [30]. The nation produces some 12 billion sanitary pads which are definitely disposable, and this amounts to about 113 000 tonnes of polymer waste year in year out [31]. The three materials most commonly used to make these pads include polyethylene (PE), polypropylene (PP) and sodium polyacrylate-based superabsorbent polymers (SAPs)- materials, which are non-biodegradable and cannot be used in the current waste-processing systems [32].

Sanitary wastes in most Indian municipalities are co-disposed with the household garbage and transported to open dumpsites or unsanitary landfills with no leachate-controlling systems [1]. Common in rural and peri-urban areas, where no form of formal waste-collection services are typically available, will be open-burning, pit-burial or direct disposition into waterways [2]. Such practices present several environmental risks, as PE and PP burning causes dioxins and furans and volatile organic compounds, whereas landfill piling causes microplastic and soil impermeability, which inhibits groundwater levels during monsoons [3].

The situational crisis is aggravated by the climatic background. In the wet monsoon season in India, the pads, which have been discarded often clog the drainage systems, which the layers of polymer drink and distend without collapsing [33]. The stagnation of water in obstructed channels aids the growth and consequent increase of the mosquitoes hence worsening the infestation of the diseases that are caused by the vectors in the overpopulated urban quarters [34]. At the same time, the hydrophobic polymer fragments that are carried away by runoff can find their way into rivers like the Ganges and Yamuna, where they can participate in microplastic pollution in the rivers, evidenced by recent sediment and fish-tissue tests [6].

The risk to the occupational health of the informal workforce, mostly predominantly of the disadvantaged women, lies in the manual handling of the unsegregated sanitary waste [7]. The lack of protective material and the social stigma of menstrual waste lead to the development of unsafe disposal patterns and the under-relating of diseases caused by contamination [8].

All these problems depict a system breakdown in the sanitary-waste management chain in India. Lack of biodegradability of polymer products, inadequate segregation at the point of production, and reliance on disposal processes that are damaging to the environment has generated a mounting ecological and human health burden [9]. The comprehension of this landscape defines the conditions of analysing the wider cascade of the environment and how material innovation will help reduce the crisis. Figure 2 illustrates the distribution of sanitary-waste disposal methods across Indian urban and rural regions, highlighting the dominance of open dumping and burning as primary end-of-life practices.

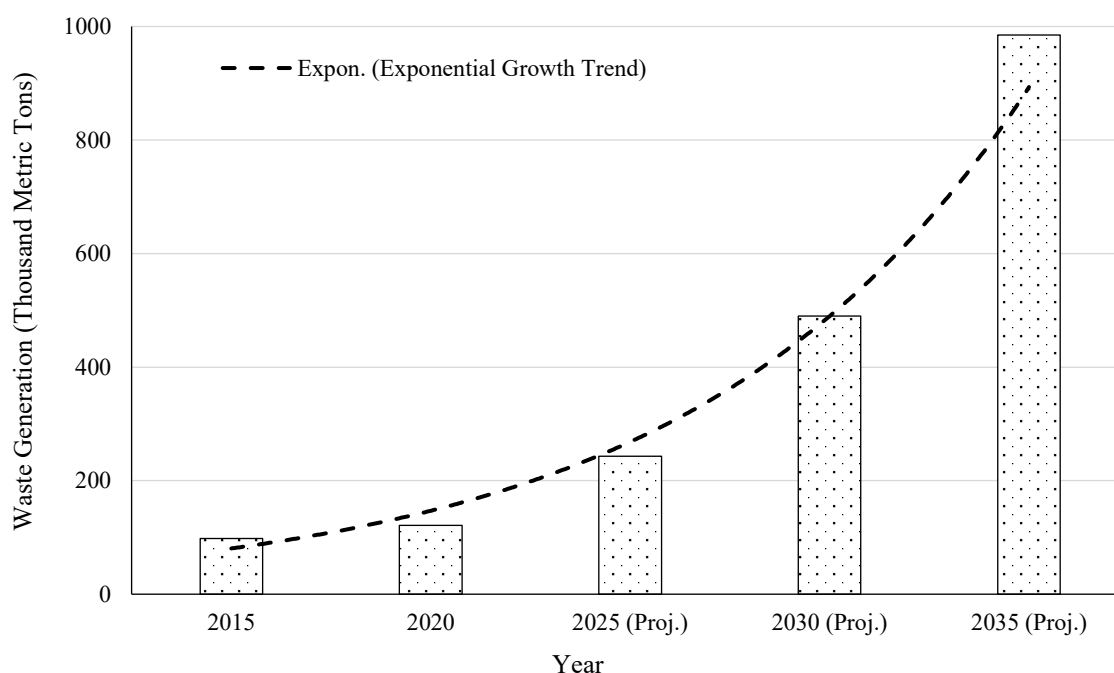


Figure 2. The bar chart titled "Estimated Annual Sanitary Pad Waste Generation in India

Source: Kumar, A., & Sharma, P. (2018). *Menstrual Products and their Disposal*. Toxics Link. <https://toxicslink.org/docs/Menstrual-Products-and-their-Disposal-Report-2018>

Macro-Scale Consequences: Overwhelming Municipal Infrastructure

Sanitary-pad polymer disposal has the environmental impacts which are spread to soil, air and aquatic ecosystems [10]. After landfill disposal or the use of open dumps, the polyethylene (PE) and polypropylene (PP) layers are slowly degraded by photodegradation and mechanical forces to generate secondary microplastics, which continue their formation in centuries [1]. These fragments permeate the topsoil decreasing the porosity and alternating the composition of the microorganisms needed to recycle nutrients. The research that has been done on landfill sites in India has reported high levels of polymeric

residues in composted soil which shows that the current biology processes are unable to breakdown such materials effectively [2].

Incidences of open burning of used pads is a common practice in most areas in India because of poor waste-collection systems [5]. Low temperature incineration of PE and PP produces toxic gases that are carcinogens and endocrine disruptors such as dioxins and furans [4]. The combined summing up of this type of pollutants in the peri-urban regions also adds to the formation of the smog in the locality and respiratory diseases especially to the informal waste collectors, as well as residents living in the vicinity [35].

The water permeation of sodium polyacrylate-based superabsorbent polymers (SAPs) in substances that decay and leach into the soil and water further increases contamination of soil and water [36]. Such hydrogel accumulates much amounts of moisture effectively hindering the natural drainage and disrupting the soil-water balance. To oceanic water, carried through monsoon runoff, polymer fragments come in contact with organic pollutants and high-density metals, which forms complicated grouping and endangers aquatic life [37]. The prolonged character of such polymers thus changing the sanitary-pad wastes into diffuse but prolonged source of environmental degradation throughout the ecosystems of India [38]. Figure 3 depicts the material flow of polymer-based pads through India's waste-management system, demonstrating the leakage pathways through which non-biodegradable components enter soil and aquatic ecosystems.

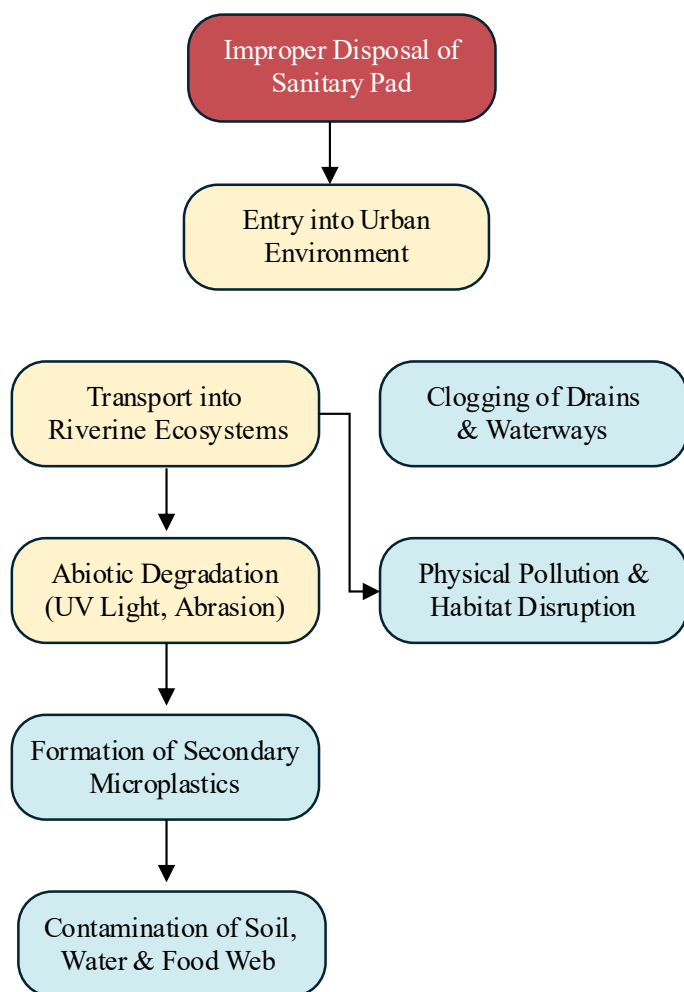


Figure 3. The Environmental Cascade Pathway of Improperly Disposed Sanitary Pad Waste
Source: Authors own illustration

Micro-Scale Consequences: The Proliferation of Secondary Microplastics

Lack of proper disposal of sanitary pads constitutes multidimensional health issues in India both in the urban and rural environment [39]. Unsegregated waste management places sanitation employees at risk of being exposed to pathogens and chemical residues, putting them at risk of skin infections, irritation of respiratory system, and disorders of reproductive tract. Incineration of plain wastes with polymer substances causes chronic exposure to dioxins and fine particulate matter particularly to women and children [40].

Indirect but dire effects of polymer runoff water contamination on community health are also indirect. Bioaccumulation through microplastic particles of PE, PP and SAPs has been observed in a few Indian rivers and this becomes a cause of concern [41]. Agricultural products and fish irrigated with contaminated water might become ways of human consumption of microplastics and connect mismanagement of menstrual waste to diets [42].

Ecologically, the presence of polymer residues in the soil disturbs the symbiosis of the microbes and reduces the fertility levels in the soils, lowering the productivity of agricultural activities in the peri-urban areas where dumping of plastics is common [4]. Combination of these human and environmental health outcomes represents a testament to the fact that sanitary-pad polymer disposal is no longer a local problem, but a growing public-health and ecological menace, which must be addressed via concerted policy means [43].

Policy and Waste-Management Gaps

India has developed several policy frameworks to control the disposal of menstrual-waste, such as the Biomedical Waste Management Rules (2016) and the Solid Waste Management Rules (2018) [44]. Nevertheless, there is poor enforcement of these legislations as they lack jurisdiction over other jurisdictions as well as poor enforcement by municipalities [7]. Sanitary waste might also be categorized in either domestic or biomedical wastes which causes confusion in collection and treatment duties [8].

Lack of segregated collection in the homes has ensured that specialized treatment or co-processing in the waste-to-energy plants do not occur [9]. Besides, the absence of economic motivation to produce biodegradable pads restricts the involvement of the industry in the process of sustainable innovation [27]. Although there are the extended producer-responsibility clauses, the monitoring mechanisms are still wanting and the informal waste handlers still deal with the hazardous materials without being subjected to any regulatory provisions [1].

As a result, gaps in policies and infrastructural shortages keep contributing to the reliance of India on the unsustainable dumping methods of garbage like open burning and landfill pouting. To overcome these failures, policymakers need to engage in concerted effort to harmonize the setting of environmental control with technological advancement, specifically, the field of biodegradable-material creation and artificial-intelligence-induced waste analytics [2].

THE PUBLIC HEALTH VECTOR: FROM HYGIENE PRODUCT TO BIOHAZARD

In addition to the serious environmental problem sanitary pads pose to the environment, the threat to the immediate and direct health issue of human beings is one of the serious problems that exist in the current context. The ultimate and most sinister aspect of such a crisis is the transformation of the disposable pad into a powerful mass health determiner. The sanitary pad, after use, is no longer an inert object, but a biologically active source of pathogenic microorganism growth. Because this biohazard is released into the environment through inappropriate disposal, creating a direct and indirect route of disease transmission, affecting the health of entire communities and disproportionately affecting those populations at the fittest.

The Discarded Pad as a Proliferation Medium for Pathogens

The antimicrobial treatment solution of the used pad basically creates an ideal micro-environment where most of the pathogens can reproduce exponentially [40]. Highly absorbent - the basis of the absorbent core is cellulose based and saturated with organic matter (blood, mucous and epithelial cells shed during anal continence) creating a nutrient rich base. The moisture is sealed in the polyolefin layers and a controlled temperature is maintained thus effectively turning the waste material into a mobile incubator [41]. Scientific observations of uncontrolled organic waste testify the very favorable conditions for the increase of opportunistic and pathogenic bacteria and fungi. Pathogenic microorganisms like *Escherichia coli* (known to cause gastrointestinal illness), *Staphylococcus aureus* (known to cause skin infections, soft tissues), and fungi like *Candida albicans* (the butt smelly jangdurs complex candidiasis) are but some common organisms found in such waste [42]. The discarded pad is therefore not just a wasteland, it is actually a living biological culture, capable of concentrating and multiplying the harmful microorganisms in the local environment.

Community Health Risks: Transmission Pathways and Vulnerable Populations

These pathogenic reservoirs are being released to the community which allows for many possible routes for spreading diseases. The paleobian, paleof dorsal, and ancient phylome of humans can be seen in the schematic shown in Figure 4, and are the perspectives through which pathogens in this waste flow can affect human health, and find their way from the source to systems of yet unsensitized populations. Water is one of the vectors. Pads thrown away in or close to water bodies or in open runoffs get washed away with rain water, resulting in contamination of surface and ground water with the contents of the pads thus contaminating drinking, cooking and bathing water [45]. The end outcome of this is high risk of waterborne diseases throughout the community.

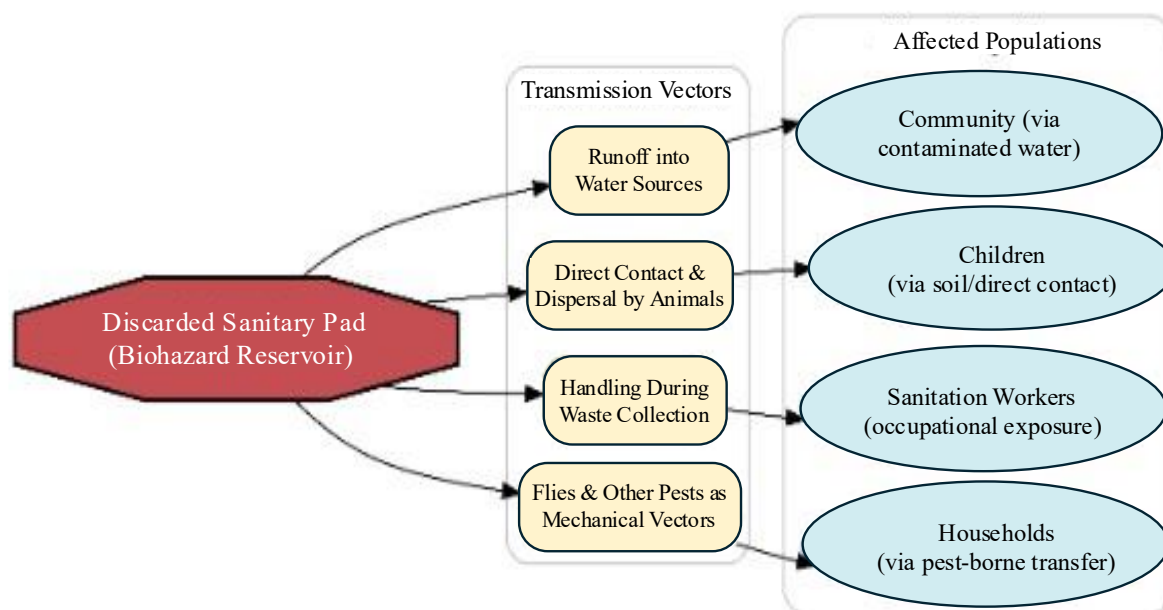


Figure 4. Transmission Pathways of Pathogens from Improperly Disposed Sanitary Waste

Source: Authors own illustration

Direct contact is one more serious risk especially to children playing in such places where garbage is openly disposed. The waste contaminating soil will sustain the pathogen and cause infections through hand to mouth or exposure to open wounds. Moreover, wild and domestic animals that forage waste may be mechanical vectors that physically spread the infected material through a larger distance, and that introduces it to the areas around human populated regions. Lastly, insects like flies may consume the organic material and then carry pathogens to food and household surfaces and pose a subtle, yet constant risk of infection in the house.

Occupational Hazards for Frontline Sanitation Workers

Whereas diffuse risks are experienced through the community, the frontline sanitation workers bear the brunt of the acute and concentrated health risks in India. This is an impoverished and unguarded workforce that has to deal with undifferentiated municipal solid waste, which is often mixed with used sanitary products [46]. These workers do not have proper personal protective equipment (PPE) in the form of impervious gloves, masks, and boots, so they are directly exposed to dermal and respiratory exposure to the biohazardous substance. This exposes them to a variety of blood-borne pathogens, such as the Hepatitis B Virus (HBV), Hepatitis C Virus (HCV), and possibly the Human Immunodeficiency Virus (HIV), in addition to the bacterial and fungal pathogens [17]. The occupational health hazards are acute and well documented, and include chronic dermal diseases and respiratory illnesses, as well as life threatening systemic infections. The inability to control the generation of the sanitary waste at the point of origin therefore transfers the greatest amount of risk to the weakest link in the waste management system [23].

The Exacerbating Role of Socio-Cultural Taboos on Disposal Practices

The socio-cultural taboos of menstruation within India make the problem of the public health crisis to be outstanding. The embarrassment, privacy, and perception of being unclean about the topic usually forces people to discard used items in a conspiratorial way. This often includes packaging them in an opaque container and disposing of them in distant places, like fields, rivers or side of the road or adding them to general domestic rubbish to hide their origin [47-49]. Although such measures are driven by the desire to enjoy privacy and dignity in the absence of safe and official discard systems, they also inadvertently negatively impact the chances for separated waste collection and treatment. This activity will ensure that the biohazardous material is widely and randomly dispersed by the environment, maximising the potential for exposure by people, and making systematic mitigation extremely difficult. The social taboo then is a high multiplier of health hazards, which is common to the population [50].

THE ARCHITECTURAL BLUEPRINT: A GENERATIVE AI PARADIGM FOR A CIRCULAR FUTURE

A systemic crisis that is rooted in material science, environmental failure and public health needs a systemic public response. Waste collection or replacement of materials is not enough. The architecture is depicted in the next section for a comprehensive solution: Generative Artificial Intelligence paradigm is an integrated, self-learning engine to be a genuinely cyclic product lifecycle. The framework transcends the issue analysis to the actual development of innovative solutions across the whole product life cycle: molecular design, end-of-life management.

The Overall System Architecture and Continuous Learning Feedback Loop

The proposed solution is a layered system of integrated intelligence engine that should be a continuous learning system. The conceptual architecture of the proposed generative AI framework as illustrated in the blueprint in Figure 5 is composed of four major interacting stages. This begins with the Data Ingestion and Synthesis Layer where the AI synthesizes and pre-processes a large and varied pool of data, including material science literature, actual data related to the waste stream, and economic and policy constraints. This synthesised information then feeds back into the Multi-Modal Generative Core, which is the bread and butter of the system, and which consists of three distinct but interlinked generative engines. Such engines will produce Actionable Generative Results, real and usable solutions such as new polymer recipes, circular designs of products and more efficient logistical systems. The final phase, the Real-World Implementation, is the implementation of these solutions through pilot programs. The outputs of these practical applications in turn feed into the Data Ingestion layer which creates a Continuous Learning Feedback Loop so that the entire system can learn, adapt and improve its generative capabilities over time.

Core Functionality 1: Generative Material Science for Biodegradability

The generative power of Artificial Intelligence (AI) provides a trail of transformative possibilities of re-engineering the material make-up of sanitary pads to biodegradability and circularity [47]. The

existing polymer root materials like polyethylene (PE), polypropylene (PP) and sodium polyacrylate-based superabsorbents polymer (SAPs) were initially created with functional efficiency and not with eco-friendliness. The challenge thus is to come up with a solution of biopolymers and natural fibre composites which do not degrade into a hot region but yield the performance measure-absorbency, tensile strength and comfort, and at the same time the, materials can be safely dismantled under natural conditions. This transition would be made possible by generative AI through the simulation of the interactions between molecules, prediction of degradation behaviour, and the proposed novel polymer structures that are minimum ecologically persistent [48].

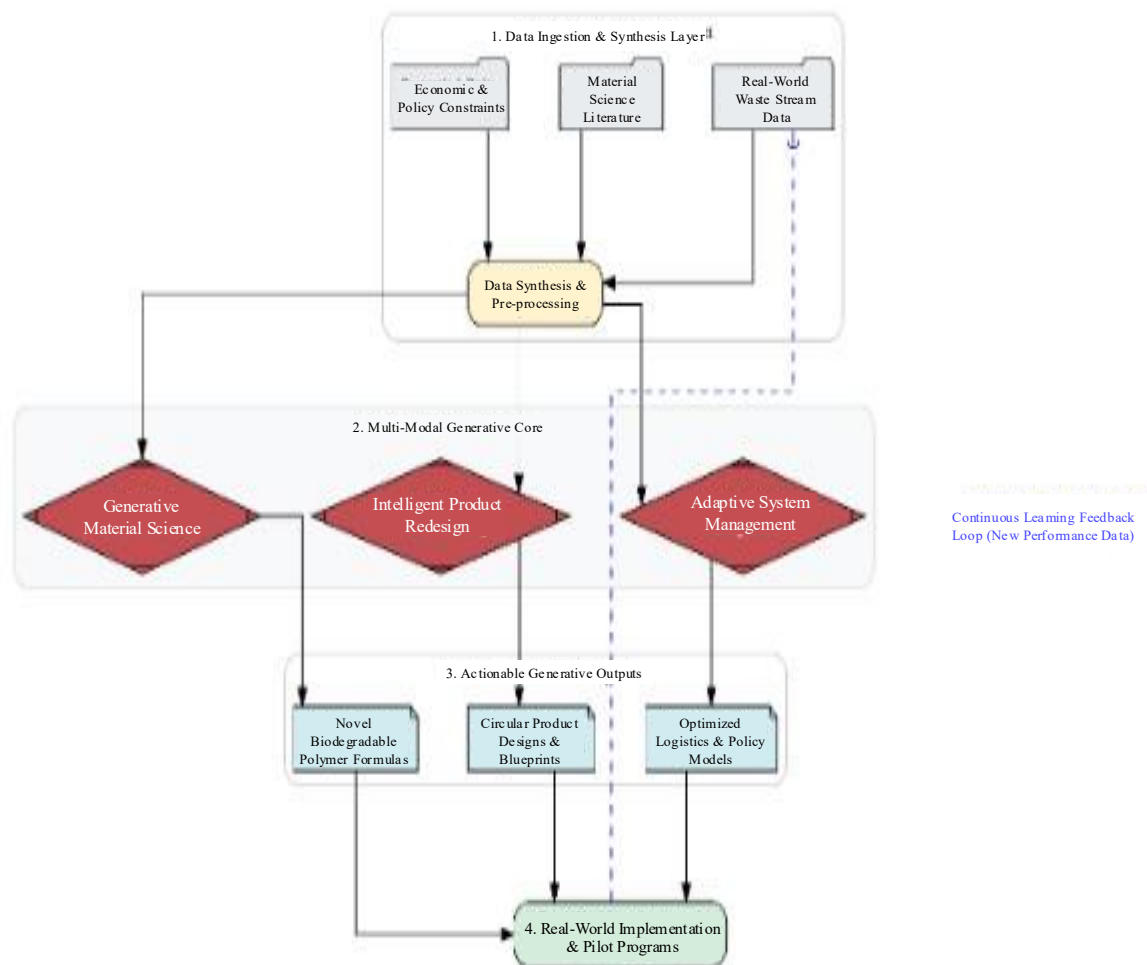


Figure 5. The Architectural Blueprint of the Proposed Generative AI Framework for a Circular Lifecycle

Source: Authors own illustration

Predictive Modelling for Sustainable Polymers

Generative AI systems are systems that combine computational chemistry, molecular dynamics, and deep learning to predict the environmental performance of alternative materials, prior to physical synthesis [49]. Accurately analysing data on the polymer structure and degradation rate on a large scale, AI models will be able to find which molecular structures are the most suitable ones in terms of biodegradation. As an example, algorithms have the ability to forecast variation in the stability to hydrolysis in the presence of ester or amide bond interactions, or the accessibility of oxygen-based functional groups to microbial recognition [50].

Polylactic acid (PLA), polyhydroxy alkanates (PHAs) and more importantly, starch based polymer blends have become promising biodegradable alternatives. PLA is a product of renewable farm

feedstocks, corn, and sugarcane, which breaks down into lactic acid in the industrial composting process. PHAs are produced via bacterial fermentation, can be tuned to have mechanical strength and can be biodegraded which means that they are useful in absorbent hygiene products. With respect to nonwoven polyolefin layers, starch and cellulose composites may also be used to create sufficient breathability and mechanical support as well as being compostable in soil.

Recognition Generative algorithms increase the finding of these materials by mechanically testing thousands of polymer variants in cost-efficiency, mechanical integrity, and by biodegradation rate. The prediction algorithm can save time in the lab experiments and can optimize the sustainable materials with respect to the tropical climatic conditions in India, with a high level of humidity and temperature that can affect the degradation behavior.

AI-Guided Biopolymer Design and Optimization

Generative design systems make use of machine learning and neural networks to optimize polymer composition at a molecular scale. It is possible to simulate the effect of modifications in monomer ratio, cross-linking density or crystallinity on biodegradability and performance parameters (absorption capacity or tensile resistance) using reinforcement-learning models.

Another significant innovation is the AI-designed bio-based superabsorbent polymers (bio-SAPs). These bio-SAPs, which are part of the hydrogel, are made out of citric acid, alginate, and cellulose derivatives rather than petroleum-derived sodium polyacrylates, and exhibit very high absorbency, yet biodegrade in soil and composting systems. The AI algorithms can be used to optimize the webbing of cross-linking and the hydrophilicity in order to maintain the structural stability operating (and disintegration upon disposal).

Besides, multi-objective optimization relying on AI can include life cycle assessment (LCA) data to optimize the environmental impact, cost, and energy input in the production process at the same time [51]. This enables scientists to develop vehicles that are not merely bio-degradable but also cost-effective in terms of mass production in the hygiene sector in India. It leads to a paradigm in which data-driven models are engaged in the sustainable development of materials in the critical role of closing the divide between environmental sustainability and viability [52].

Implications for Circular Material Economy

The deployment of Generative AI in the material science industry causes an ecosystem of closed-loop of the sanitary-product system, which allows the entire production, use, and disposition of the product to be recircled in a circular economy [53]. Designing biopolymers with AI is the way to make sure that post-use products can safely go back to the environment and there will be no long-term pollutions after usage to avoid the need to use landfill or incineration. Also, AI-optimized polymers can be converted into biodegradable pads that can be integrated into decentralized composting or biogas systems and provide a more sustainable alternative to the current pattern of waste-management [54].

In the case with developing economies including India where the waste segregation and collection systems are still fragmented, the transition to biodegradable substances will be a practical gesture that will reduce the end-of-life complexity [55]. Generative AI removes the necessity of post-use segregating or chemically treating because biodegradability is built in at the molecular level. The strategy will make the production-disposal cycle of sanitary-pad making a regenerative cycle of materials and will help directly in achieving national objectives under the Swachh Bharat Mission and the United Nations Sustainable Development Goals (SDG 12: Responsible Consumption and Production) [56].

Generative AI reinvents material innovation by integrating the computationally intelligent with the ecological. The hygienic industry can move to the use of environmentally friendly materials by

predictive modelling of bio-based polymer such as PLA, PHA, cellulose composites and citric-acid SAPs without sacrificing the performance of the product. It is a clear milestone toward the concept of circularity, environmental safety and scalable industrial implementation: AI-driven material discovery and sustainable engineering.

Core Functionality 2: Intelligent Product Redesign for Disassembly

The second generative module helps deal with the issue of the composite nature of the product. Its role is to re-design the sanitary pad itself, moving the design philosophy away towards permanent assembly and more towards a deliberate disassembly. This engine would produce new product architectures that reduce the number of non-biodegradable materials used and made it easy to separate the materials after use. It would produce generative results in the form of detailed 3D models and designs of modular pads, in which, as an example, an absorbent biopolymer core would be easily dissociated with an outer reusable cover. It would also produce optimal material composition lists and manufacturing process flowcharts specifically designed to be used in low-resource environments so that the redesigned products are not only sustainable but also cost-effective and affordable. The purpose behind this functionality is to develop a circular product.

Core Functionality 3: Adaptive Logistics for Waste Management

The third generative module addresses the infrastructural and the health crises in the community in Sections 3 and 4. It is meant to develop smart, adaptive and context-sensitive waste management systems. Based on real-life data on the geography of cities, population density, and the current infrastructure, this AI would produce optimized logistical frameworks of the segregated collection of sanitary waste. The deliverables would be dynamic collection route maps, which are responsive to the changing conditions, predictive models to assist the municipalities to plan on future infrastructure requirements, and simulated policy impact evaluation to guide proper regulations. The engine is developed to establish a safe, economical, and responsible system of the management of this very category of waste, which will allow closing the loop and directly reduce the environmental and personal health risks. All of the main functions of the generative framework are meant to deliver particular, operational outputs that relate to various aspects of the lifecycle crisis. Table 1 illustrates the unique functions and output of each AI module.

Table 1. Functional Summary of the Generative AI Framework Modules

Source: Authors own illustration

Framework Module	Primary Function	Generative Outputs	Problem Addressed
Generative Material Science	To invent novel, sustainable polymers by exploring vast chemical design spaces.	<ul style="list-style-type: none"> • Candidate molecular structures for biodegradable SAPs. • Predicted material property data (e.g., absorbency, tensile strength). • Simulated degradation pathways and byproducts. 	Material Science Impasse (Section 2)
Intelligent Product Redesign	To design new sanitary pad architectures optimized for circularity and low-impact manufacturing.	<ul style="list-style-type: none"> • 3D models of pads engineered for easy disassembly. • Material composition lists with reduced polymer content. • Manufacturing process flowcharts for low-resource settings. 	Environmental Cascade (Section 3)
Adaptive System Management	To create and optimize logistical and waste management systems for specific environments.	<ul style="list-style-type: none"> • Optimized collection route maps for segregated waste. • Predictive models for municipal infrastructure needs. • Simulated policy impact assessments. 	Public Health Vector (Section 4)

UNLOCKING SYSTEMIC CHANGE: INDUSTRIAL AND POLICY IMPLICATIONS

The generative architecture of the architectural model introduced in the previous section is not simply a technical proposal, it is a promise of systemic change. Its use has dramatic implications beyond the laboratory and into the world of industrial practice, policy and economics. In order to transform the currently linear model into an AI-based circular one, one will have to rethink the production, control, and value of absorbent hygiene products altogether. It is in this section that these wider industrial and policy implications are discussed, whereby the new paradigms that emerge when the end-of-life of a product is not considered as an externality but rather as part of the product's design are outlined.

A New Paradigm for the Absorbent Hygiene Industry

The use of the proposed generative AI model would challenge the absorbent hygiene industry to move from its current model (based on the sale of products) to a life-cycle stewardship model. Under the current paradigm the liability of a manufacturer ceases at the point of sale. The role of the manufacturer in the proposed circular model is in the lifecycle of the materials in general. The potential of the AI in creating new and proprietary biopolymers and circular design of products means that the competitive advantage from lower cost of production would be shifted to original sustainability. A commercial option would be to create a regulatory cost which would encourage research and development to make products that are not only effective but demonstrably biodegradable or readily recyclable.

This conversion would also open up new business models that would work on the basis of material recovery and re-use. The management of resource streams could be the diversification of an industry which now manufactures disposable goods. For example, a manufacturer may have a composting plant or be working with one to recycle its biodegradable components, or deconstruct and recover materials of its circular-design products. The adaptive logistics layer of the AI would be a critical enabler of these new models and the data-driven intelligence that would make such systems of recovery effective and profitable. Product lifecycle therefore becomes more of two-way street than a one-way street with dead-end product being used by a new generation of material creating economic value but losing environmental harm.

Reforming Municipal and National Waste Management Policies

The application of this AI-based paradigm would also have transformative impact on the policy and regulatory arena of the population. The current municipal solid waste management policies are predominantly reactive, that is, to accept mixed, unsorted and undifferentiated waste through the blunt instruments of landfills and incinerators. The framework raised allows for a change in the approach to the waste management to an active one and a very specific one. The programmable logistics engine of the AI can provide city planners with effective predictive articulation to design and install segregated systems of collection targeted on specifically collecting sanitary waste, and segregate it as a potential biohazard and valuable resource.

On a national level, the new technological capability would provide utility for adopting such policies as Extended Producer Responsibility (EPR). With an EPR approach, manufacturers dropped financially and logistically responsible in relation to the end of life of their products. In the past, EPR implementation in regards to the case of sanitary pad has been a complex task due to the waste stream [42]. Nevertheless, EPR is a viable and effective regulatory mechanism with AI-designed products that are designed to facilitate disassembly, along with AI-optimized collection systems, in place. It would be possible to set certain, data-driven aims on the rates of material recovery or biodegradation which might be set by policymakers, and the AI structure would provide the technology exist to the industry to achieve the above goals set. Regulation therefore would not be a punitive tool in regulation of pollution, rather it would be an incentive to innovation in the matters of sustainability.

The Economic Potential of a Localized Circular Materials Economy

Finally, there is the likelihood that the popularization of this paradigm would create a more robust and localized circular materials economy. Fossil Fuel polymers are dependant on the world wide supply chart of the existing linear model. An AI-based system, with the added challenge of ensuring that biodegradable materials are a priority, would require using feedstocks that are domestically sourced e.g. agricultural wastes to manufacture biopolymers [43]. Similarly, the localized systems of Mateial recovery and composting would create a new source of economic activity and employment in green technology industry and garbage management industry. This paradigm helps make an economy more self-reliant and more sustainable through the treatment of waste as something that can be utilized, rather than something that must be disposed of. The financial potential in fact is much wider than the absorbent hygien industry itself providing a proposal of how this generative AI can be used to transform the other sole industry that has been plagued by the legacy of linear, disposable design.

CHARTING THE PATH FORWARD: A RESEARCH AND DEVELOPMENT AGENDA

Generative AI paradigm contains the blueprint of architecture that enables data to give a plausible model to a product life cycle in a circle. The shift of the architectural design into the functioning and substantive reality, however, involves planned and thoroughly interdisciplinary research and development agenda. Successful application of the paradigm will be followed by the preliminary resolution of the basic questions in data analysis, requires widespread collaborative efforts in the science level and a gradualization of the procedure to mitigate and guarantee its efficiency. This section of the paper tracks this path, however, by detailing the type of key research and development work which would be necessary to actualize such a game changing vision.

Foundational Data Requirements for AI Model Training

The quality, ultimately the diversity and size of any artificial intelligence system is actually determined by the data the system is being trained on. The three categories, which, yet, different, data sets must be managed within the proposed framework. The former would comprise a comprehensive database of material science data, comprising comprehensive, catalogue databanks on chemistries of polymers, the physical properties, particularly the tensile strength, of these polymers, and, most valuable, the degradation of the polymers under various environmental factors and the degradation products. Not just deconsolidation of already-existing digital databases, but the application of natural language processing techniques to extract, process, and format useful data in decades of scientific publications.

The second is the waste stream data in the actual world, i.e. India. This would include geolocated, granular data on the composition of municipal solid waste, the measured proportion of sanitary products in that waste and leakage into the environment. This information is of fundamental importance for the training of the adaptive logistics module as well as for giving the generative core a realistic perception of the end-of-life complexities. The third category which is required is the socio-economic and policy data. This will contain data on the cost of manufacturing, the source of raw materials, the way consumers buy products, and the particular limitations existing and possible environmental laws. The generative outputs of the AI would be purely theoretical without these rich and multi-modal datasets, and the AI can be trained to deliver solutions that are scientifically innovative, economically feasible and context-specific.

The Imperative for Interdisciplinary Collaboration

The nature of the issue at hand makes it complex in nature and thus makes any one discipline the key to a solution. A research and development agenda should thus be constructed on a platform of profound and long lasting interdisciplinary cooperation. The project will need an interdependent group of professionals, with the experience of one area shaping the activities of the other. The core generative models require artificial intelligence and machine learning experts to design, develop and train them. Nonetheless, they should perform their work in a consistent consultation with polymer scientists and

chemical engineers, who can verify the chemical plausibility of the materials produced by AI and instruct the AI to explore the design space of chemicals.

At the same time, environmental scientists must establish precise models on the effects of the ecosystem, which represent the feedback required to determine the actual sustainability of a proposed material or system. To assess the health risks of the existing system and to quantify the advantages of suggested interventions, the data and frameworks have to be provided by the professionals of the field of public health and epidemiology. Lastly, social scientists, economists and policy gurus are also needed in order to comprehend the human behaviors behind disposal practices, as well as, to ensure the solutions crafted thereof have to be culturally sensitive, economically viable, and able to be incorporated into effective public policy. It is not a sequential process but rather a co-creative process, with all disciplines collaborating simultaneously to define and streamline the answers that the AI framework has produced.

A Phased Approach to Validation: From Simulation to Pilot Programs

To introduce such a potent technology in the market, a progressive process of validation will be required which serves as the application of the technology on the virtual aspect to the real world to reduce the risk and collecting data which is important as each phase is made. In silico validation constitutes a process where, the entire system is simulated in an entirely computerized environment. At this point, advanced simulations would, in turn, strictly test the calculations of new materials and product designs and their performance, cost, and environmental impact with the help of the AI. This will allow the search through thousands of potential solutions in a low cost way of finding the most promising ones.

The second one is the laboratory validation. Identified computer based candidate materials will be produced under control in a laboratory. Conversely, USG hosts of their physical characteristics (absorbency, durability and rate of biodegradation under various conditions) would be empirically established. It is an important move in ensuring the predictive models of the AI are past correct and to supply real-life information on perfecting the models. Implementation of controlled pilot programs is also the third and the most vital step to be taken. Again in a small and carefully-supervised area of geography, a total and complete product, and the collection system, would be abstracted. This empirical test is an excellent source of knowledge of user acceptance, production issues, collection efficiency, and their real environmental impact. Out of this information can then be the foundation of an endless learning feedback loop and the following generation of solutions can then optimize on its own on empirical performance. Such a gradual nature will assist in making sure that the paradigm can not only be theoretically tested, but also practically functional and may be implemented on the scale.

AN ACTIONABLE MANDATE: RECOMMENDATIONS FOR A POST-WASTE WORLD

Converting a theoretical into a real model requires more than a research plan, it is a focused and brainstormed pitch by all the stake holders involved in a product lifecycle. The generative AI paradigm is so powerful technology that it cannot exist in a vacuum. The success of this it relies on the establishment of the enabling policy environment, and the development of the progressive industrial dynamics and participatory science. This article is a call to action and incorporation, more specific and narrowed prescriptions to policy-makers, industry players and the scientific community. The recommendations are not prescriptive, but a road map with which together we can create a post-waste world.

For Policymakers: From Regulation to Incentivization

The task of government is to establish a regulatory environment that causes the status quo to be untenable and the alternative that is sustainable to be inevitable. The initial and the most urgent policy proposal is the effective use and the strict adherence to Extended Producer Responsibility (EPR) systems. The legal requirement that a manufacturer is financially and logistically liable in end-of-life

management of its products, EPR directly internalizes the cost of pollution, establishing a strong economic incentive to companies to implement the principles of the circular design arising within the AI framework.

Second, governments must stop regulating and start to provide incentives to innovate. This can be done through offering grants, tax credits and other forms of financial assistance towards research and development in sustainable materials and technologies of the circular economy. Pilot programs outlined in the research agenda should be federally funded to de-risk the innovation process to the private industry and hasten the transition. Lastly, the policymakers should engage in massive public awareness initiatives aimed at desensitizing menstruation and informing citizens about the need to use proper disposal and the presence of new sustainable alternatives. In the success of any waste collection system that has been segregated, an informed population is an important ally.

or Industry Leaders: From Compliance to Innovation

The message to the absorbent hygiene industry is that it has to move from a paradigm of offensive (proactive innovation) to a paradigm of defense (compliance with regulation). Industry leaders are being encouraged to invest in sustainable research and development in the long term and the generative AI architecture should no longer be regarded as a threat, but as an asset. The key measure is to carry out the core idea of Design for Disassembly, that is, considering end-of-life of objects as the first principle of their design, which has to be ensured by the intelligent redesign module of AI. Further, the sector will need to transform to the radical disclosure of lifecycle impact reporting. Businesses should help drive licensed and trusted information in the marketplace about the contents of what they sell, their supply chain and that product's impact on or utilization of the environment at the end of its life. On the basis of such transparency, consumer confidence will be generated and an ecosystem created where sustainability forms the basis of differentiation. Taking the lead in the switch to a circular model will allow the industry to reduce the environmental footprint, gain extra revenue streams, and gain brand reputation and then work on it as a long-term social licence to operate.

For the Scientific Community: From Silos to Synergy

The bridging technology to construct and exhibit the technologies of this new paradigm lies in the field of science. The former is the initial proposal of an integrated collaboration to develop open-source infrastructures and curations in materials informatics. The robust generative models are trained on the high quality common datasets of polymers properties, degradable pathways. This pre-competitive cooperation will assist accelerate innovation across the industry.

The second and significant condition is that it must build a profound and grave inter-disciplinary collaboration. Barriers between the domains of computer science and polymer science, environmental science and the field of public health should be eliminated. The policies would need to be developed by higher education and funding agencies that will encourage and promote such forms of research that would encourage interaction between such disciplines in order to actually design complex problems of the real world. Lastly, the scientific community should be committed to incorporating the issue of public health in the study of environmental science. Base variables in the description of any new material or a new system should include social and environmental cost of pollution so that solutions that have to be found are not only environmentally good, but also socially just and health wise good to mankind.

For Non-Governmental and Community Organizations: From Advocacy to Action

The most important transition institution between macro and grassroots reality is constituted of non-governmental organizations (NGOs), groups of civil society and community-based organizations. Their initial previous employment is to become the advertisers of the popular education and adoption. These organizations are best placed to translate technical scientific and policy data into simple culturally relevant educational and community informative initiatives that can impact through social taboos and create community confidence in new sustainable products and new disposal systems.

Second, such associations are to become independent watchdogs and lobbyists. They may be important in the assessment of the real results of pilot programmes and implementation of EPR policies as a process of disincentive to industry and governments to have their promises to them. Lastly, the localised solutions cannot be co-designed and implemented without the community-based organisations. Community consultation will assist them in making sure that the adaptive logistical models of the AI are adjusted to the local environment of a given village or city neighbourhood, such that the systems are not only technologically up-to-date but also realistic, convenient, and fair.

CONCLUSION

The present situation of disposable sanitary pads irresolvably contradicts all the modern excesses-the product which offers people liberty and dignity now leaves behind constant, gnawing pollution which is ever swelling. This crisis has been systematically dismantled in this paper in an effort to accuse it as not only a waste management crisis, but of a crisis of design, construction with another dead-end literature, our choosy ratifications of the take-make-dispose linear economic model, which more than conveniently validates itself. When a nightmarish architecture is cut and polished by an amalgamation of socio-infrastructure realities, the acute ecological cascade, and a raging case study is a terrifyingly real and agonizing story about the narration of a grim future about the condition of the Indian experience.

This conflict has debunked any hastening in regard to any solution to an issue of this magnitude. As a fact, the solution will study a paradigm of change, a paradigm of reactive waste management to proactive waste management, in other words: planning an architecture to prevent the wastes. The novel solution to this problem-as a Generative Artificial Intelligence framework is offered in this aspect. It is not a mere analytical instrument; instead, it is a creative engine that traverses the product life cycle adaptation. This concept of AI can create a pathway to go through a linear problem toward a circular resolution through autonomous designing of newly produced biodegradable materials, circular designing of products, and designing safe and efficient systems. Lastly, the framework suggested here is not only some form of explicit solution to the particular waste issue of sanitary pads but more of a future beacon of calling on the most cutting-edge technologies to put to labor the elimination of our most deeply-rooted environmental and population health issues.

REFERENCES

1. Ahmad, A., & Sharma, M. (2024). Menstrual waste behaviour of young adolescents: a study from a gender perspective. *Journal of Water, Sanitation and Hygiene for Development*, 14(9), 833–842. <https://doi.org/10.2166/washdev.2024.120>
2. Amery, F., McLaren, H.-J., & Padhee, S. (2025). Where is menstruation in global health policy? The need for a collective understanding. *Global Public Health*, 20(1), 2448272. <https://doi.org/10.1080/17441692.2024.2448272>
3. Batra, R., Paliana, G., Uberuaga, B. P., & Ramprasad, R. (2019). Multifidelity information fusion with machine learning: A case study of dopant formation energies in hafnia. *ACS Applied Materials & Interfaces*, 11(28), 24906–24915. <https://doi.org/10.1021/acsami.9b02174>
4. Batra, R., Song, L., & Ramprasad, R. (2021). Emerging materials intelligence ecosystems propelled by machine learning. *Nature Reviews Materials*, 6, 655–674. <https://doi.org/10.1038/s41578-021-00309-6>
5. Beyond Plastics, & Just Zero. (2023, January). Model packaging reduction and recycling act. Beyond Plastics. <https://www.beyondplastics.org/s/Model-Packaging-Reduction-and-Recycling-Act-January-2023.pdf>
6. Bhatt, P., Pathak, V. M., Beg, M. A., & Singh, A. (2025). Recent perspectives of microplastic analysis from sampling to characterization. *Environmental Science and Pollution Research*. Advance online publication. <https://doi.org/10.1007/s11356-025-48123-y>
7. Carraher, C., Roner, M., Shahi, K., Barot, G., & Barot, S. (2017). A review of polyolefins. *Journal of Macromolecular Science, Part C: Polymer Reviews*, 57(4), 353–385. <https://doi.org/10.1080/15583724.2017.1367006>

8. Chavan, V. D., & Kulkarni, P. S. (2023). A critical review on technological development of cellulosic superabsorbent polymers and their application. *Chemical Engineering Journal*, 474, 145512. <https://doi.org/10.1016/j.cej.2023.145512>
9. Chen, J., Chan, D. Y., Yang, T. T., Parisi, D., Reuvers, B., Veldhuis, T., Picchioni, F., Wu, J., & Koning, C. (2025). Bio-degradable, fully bio-based, thermally cross-linked superabsorbent polymers from citric acid and glycerol. *Green Chemistry*. Advance online publication. <https://doi.org/10.1039/d4gc06323f>
10. Chen, J., Veldhuis, T., Wu, J., & Koning, C. E. (2017). Synthesis of super absorbent polymer using citric acid as a bio-based monomer. *Polymer Degradation and Stability*, 144, 198–206. <https://doi.org/10.1016/j.polymdegradstab.2017.08.016>
11. Das, P., & Mohapatra, S. (2023). Menstrual hygiene management in India: The concerns and the solutions. *Qeios*. <https://doi.org/10.32388/4GBGQO>
12. de Souza, M. A., &Lirani, D. R. (2024). Photocatalytic degradation of microplastics in aquatic environments: Materials, mechanisms, practical challenges, and future perspectives. *Water*, 17(14), 2139. <https://doi.org/10.3390/w17142139>
13. Ibikunle, A. O. A., Alagbe, E. O., Odusote, F. A., & Ganiyu, S. A. (2015). Performance characteristics of local and imported sanitary pads. *International Journal of Engineering and Technology*, 5(6), 461-465.
14. El-Saied, H., Al-Otaibi, K. M., Al-Ghamdi, A. Y., & Al-Zahrani, S. M. (2022). Synthesis, characterization, and swelling properties of a new highly absorbent hydrogel based on carboxymethyl guar gum reinforced with bentonite and silica particles for disposable hygiene products. *ACS Omega*, 7(43), 39002–39018. <https://doi.org/10.1021/acsomega.2c05342>
15. European Environment Agency. (2022). Early warning assessment related to the 2025 targets for municipal waste and packaging waste: Italy. Publications Office of the European Union. <https://www.eea.europa.eu/publications/many-eu-member-states/italy>
16. Foteinis, S. (2020). After-life management of single-use absorbent hygiene products: A review. *Waste Management & Research*, 38(6), 597–611. <https://doi.org/10.1177/0734242X20916834>
17. Fourcault, A., Scherer, L., &Cucurachi, S. (2022). Life-cycle assessment of menstrual products: A comparison of pads, tampons, menstrual cups and menstrual underwear. *The International Journal of Life Cycle Assessment*, 27, 1373–1385. <https://doi.org/10.1007/s11367-022-02085-7>
18. Geertz, A., Kim, S., Kirk, K., & Harris, A. (2016). Menstrual health in East and Southern Africa: A multi-country landscape analysis. UNICEF.
19. Huo, Z., Xie, X., & Tong, R. (2025). Machine learning for developing sustainable polymers. *Chemistry – A European Journal*, 31(1), e202500718. <https://doi.org/10.1002/chem.202500718>
20. Ibikunle, A. A., Titiloye, M. O., &Omueti, O. (2015). Performance characteristics of local and imported sanitary pads. *International Journal of Engineering and Technology*, 5(4), 322–326.
21. Kern, J., Su, Y., Gutekunst, W., & Ramprasad, R. (2025). An informatics framework for the design of sustainable, chemically recyclable, synthetically accessible, and durable polymers. *npj Computational Materials*, 11(1), Article 23. <https://doi.org/10.1038/s41524-025-01421-x>
22. Kumar, A., & Sharma, P. (2018). Menstrual products and their disposal. *Toxics Link*. <https://toxicslink.org/docs/Menstrual-Products-and-their-Disposal-Report-2018.pdf>
23. Li, X., Liu, Y., & Hou, L. (2023). Machine learning-assisted design of polymeric materials: Recent advances and future trends. *Accounts of Materials Research*, 5(1), 29–42. <https://doi.org/10.1021/accountsmr.3c00288>
24. Liu, Z., Zhang, X., Chen, Y., Zhao, P., & Hou, J. (2025). Using classifiers to predict catalyst design for polyketone microstructure. *Organometallics*. Advance online publication. <https://doi.org/10.1021/acs.organomet.5c00321>
25. Luo, J., Zhang, C., & Zhang, J. (2024). Sustainable coagulative removal of microplastic from aquatic systems: Recent progress and outlook. *Environmental Science & Technology*, 58(30), 13625–13642. <https://doi.org/10.1021/acs.est.4c03251>
26. Muench, F., & Wendt, G. (2022). Spotlight on the life cycle of acrylamide-based polymers supporting reductions in environmental footprint: Review and recent advances. *Polymers*, 14(1), 173. <https://doi.org/10.3390/polym14010173>

27. National Research Council. (2019). Closing the loop on the plastics dilemma. The National Academies Press. <https://doi.org/10.17226/25498>
28. Niu, Q., Liu, Z., Sun, J., & Fan, B. (2025). Superabsorbent polymers: Synthesis, applications, and biodegradability. *ChemistrySelect*. Advance online publication. <https://doi.org/10.1002/slct.202502854>
29. Pattanayak, R., Singh, N., & Meena, R. (2023). Recent advancement of bio-based superabsorbent polymers: A review emphasizing biodegradability. *Journal of Polymer Research*, 30(5), 193. <https://doi.org/10.1007/s10965-023-03577-z>
30. Ragaert, K., Delva, L., & Van Geem, K. (2017). Mechanical and chemical recycling of solid plastic waste. *Waste Management*, 69, 24–58. <https://doi.org/10.1016/j.wasman.2017.07.044>
31. Kumar, A., & Sharma, P. (2018). Menstrual Products and their Disposal. *Toxics Link*.
32. Ramaswamy, S., & Shaukath, A. (2024). Swachh Bharat Mission – A transformative shift in Bharat's sanitation landscape. BlueKraft Digital Foundation. <https://www.bluekraft.in/wp-content/uploads/2024/09/Swachh-Bharat-Decadal-Journey-Report.pdf>
33. Samantaray, P. K., & Little, A. (2023). Emerging trends in machine learning for polymer science. *ACS Polymers Au*, 3(3), 263–274. <https://doi.org/10.1021/acspolymersau.2c00053>
34. Ayrilmis, N., Kanat, G., YildizAvsar, E., Palanisamy, S., & Ashori, A. (2025). Utilizing waste manhole covers and fibreboard as reinforcing fillers for thermoplastic composites. *Journal of Reinforced Plastics and Composites*, 44(17-18), 1108-1118.
35. Ramasubbu, R., Kayambu, A., Palanisamy, S., & Ayrilmis, N. (2024). Mechanical Properties of Epoxy Composites Reinforced with Areca catechu Fibers Containing Silicon Carbide. *BioResources*, 19(2).
36. Aruchamy, K., Karuppusamy, M., Krishnakumar, S., Palanisamy, S., Jayamani, M., Sureshkumar, K., ... & Al-Farraj, S. A. (2025). Enhancement of Mechanical Properties of Hybrid Polymer Composites Using Palmyra Palm and Coconut Sheath Fibers: The Role of Tamarind Shell Powder. *BioResources*, 20(1).
37. Karuppiah, G., Kuttalam, K. C., Palaniappan, M., Santulli, C., & Palanisamy, S. (2020). Multiobjective optimization of fabrication parameters of jute fiber/polyester composites with egg shell powder and nanoclay filler. *Molecules*, 25(23), 5579.
38. Palanisamy, S., Kalimuthu, M., Santulli, C., Palaniappan, M., Nagarajan, R., & Fragassa, C. (2023). Tailoring epoxy composites with Acacia caesia bark fibers: Evaluating the effects of fiber amount and length on material characteristics. *Fibers*, 11(7), 63.
39. Santulli, C., Palanisamy, S., & Kalimuthu, M. (2022). Pineapple fibers, their composites and applications. In *Plant Fibers, their Composites, and Applications* (pp. 323-346). Woodhead Publishing.
40. Sanitation & Hygiene Fund. (2023). Power in her hands: Menstrual equity for all. <https://www.shfund.org/sites/default/files/2024-03/SHF%20MHH%20approach%20April%202023.pdf>
41. Schuett, T., Endres, P., Standau, T., Zechel, S., Albuquerque, R. Q., Brütting, C., Ruckdäschel, H., & Schubert, U. S. (2024). Application of digital methods in polymer science and engineering. *Advanced Functional Materials*, 34(15), 2309844. <https://doi.org/10.1002/adfm.202309844>
42. Scott, G. (2015). “Green” polymers. *Polymer Degradation and Stability*, 122, 118–122. <https://doi.org/10.1016/j.polymdegradstab.2015.10.012>
43. Shetty, A., Kumar, N., & Kasar, P. (2023). A review on challenges in polymer processing for additive and formative manufacturing methods within the framework of sustainability. *Polymers*, 15(24), 4649. <https://doi.org/10.3390/polym15244649>
44. Stein, E., & Kim, S. (2009). Flow of funds: The political economy of menstrual privacy. In C. Bobel (Ed.), *New directions in critical menstruation studies* (pp. 235–256). Palgrave Macmillan.
45. Sunny, A. R., Sazzad, S. A., Islam, M. A., Mithun, M. H., Hussain, M., Raposo, A., & Bhuiyan, M. K. A. (2025). Microplastics in aquatic ecosystems: A global review of distribution, ecotoxicological impacts, and human health risks. *Water*, 17(12), 1741. <https://doi.org/10.3390/w17121741>

46. TechSci Research. (2025, July). India hygienic product market, by type, by end user, by distribution channel, by region, competition, forecast & opportunities, 2019-2030F. <https://www.techsciresearch.com/report/india-hygienic-product-market/5068.html>
47. TechSci Research. (2025, July). India sanitary pads market, by product type, by distribution channel, by region, competition, forecast & opportunities, 2020-2030F. <https://www.techsciresearch.com/report/india-sanitary-pads-market/7472.html>
48. Thakare, S., & Singh, A. (2020). Market landscape for menstrual health and hygiene management (MHM) incinerators in India & South Africa. RTI International. <https://gatesopenresearch-files.fl1000.com/posters/docs/gatesopenres-197047.pdf>
49. Thomas, N. L. (2016). The development and properties of polyolefin-based packaging films. *Comprehensive Materials Processing*, 12, 1–28. <https://doi.org/10.1016/B978-0-08-096532-1.01201-9>
50. van der Zee, M. (2015). Biodegradable polymers: An overview. In *Bio-based plastics* (pp. 75–104). Springer. https://doi.org/10.1007/978-3-319-13931-5_4
51. Vasile, C., & Pamfil, D. (2017). Recent advances in management of plastic waste. In *Management of microbial resources in the era of climate change* (pp. 317–356). Springer. https://doi.org/10.1007/978-3-319-52949-8_13
52. World Health Organization. (2021). Global strategy on digital health 2020-2025. <https://www.who.int/docs/default-source/documents/gd4dh.pdf>
53. Yang, L., & Zhang, Y. (2024). The pursuit of advanced polymers for energy technologies: Overcoming data fragmentation with FAIR principles and AI. arXiv preprint arXiv:2505.13494. <https://doi.org/10.48550/arXiv.2505.13494>
54. Zarrintayebi, G., & Asefnejad, A. (2024). Advances in hydrogel film fabrication and functional applications across biomedical and environmental fields. *Applied Sciences*, 15(17), 9579. <https://doi.org/10.3390/app15179579>
55. Zhu, Y., Romain, C., & Williams, C. K. (2016). Sustainable polymers from renewable resources. *Nature*, 540(7633), 354–362. <https://doi.org/10.1038/nature21001>
56. Ghosal, I., Saxena, D., Rajak, R., Gulati, K., & Kalaria, S. (2025). AI-driven sustainable supply chain framework for polymer composite production. *Journal of Polymer and Composites*, 13(5), 219–235. <https://journals.stmjournals.com/jopc/article=2025/view=225280/>