Alternatives to Single Use Plastics (SUPs)

White Paper by DST-Amrita TEC Centre

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Abstract:

Single-use plastics (SUP) have emerged as a significant environmental concern due to their widespread use in various industries. This report aims to shed light on the current state of research on alternatives to SUP within India, their potential for commercial application, consumer behavior, and regulatory frameworks in India. The environmental impact of SUP cannot be ignored, as their disposal contributes to pollution, marine debris, and ecosystem degradation. Recognizing the urgency of the situation, researchers and innovators in India have been actively exploring sustainable alternatives to SUP, and significant progress has been made in recent years. These efforts primarily focus on developing bio-based materials, such as bioplastics derived from renewable resources, and promoting reusable or compostable packaging. The goal is to minimize environmental harm while ensuring that the alternatives meet the functional requirements of the end applications.

Furthermore, advancements in material engineering and processing techniques have played a pivotal role in improving the performance and cost-effectiveness of these alternative solutions, rendering them more viable for commercial applications. Industries have already begun to embrace sustainable packaging solutions to meet the growing consumer demand for eco-friendly products. However, challenges such as scalability, cost competitiveness, and effective end-of-life management still need to be addressed through further research and development. To transition from SUP, governments, and organizations must implement financial incentives and policy regulations that incentivize sustainable alternatives. Additionally, robust regulatory frameworks must be developed to restrict the production and consumption of SUP, promote the establishment of recycling and composting infrastructure, and encourage the widespread adoption of environmentally friendly consumption practices.

1. Introduction

In 2018, Collins Dictionary named 'single use' the word of the year, defining it as something "made to be used only once." This recognition primarily stemmed from its association with plastic, highlighting the significant impact single-use plastics (SUPs) have on our lives. Single-use plastics encompass disposable plastic products designed for short-term use or a brief duration before disposal. Numerous items fall into this category, serving purposes related to packaging, convenience, and single servings. Examples include plastic bags, straws, food packaging, disposable cutlery, water bottles, and coffee stirrers. Typically derived from petroleum-based materials like polyethylene (PE), polypropylene (PP), polystyrene (PS), or polyethylene terephthalate (PET), single-use plastics are lightweight, durable, and cost-effective to produce. They offer convenience and affordability, leading to their widespread usage. Single-use plastics fulfill various functions depending on their intended use, such as carrying groceries, drinking beverages with straws, consuming food on the go with disposable cutlery, and storing/transporting food with plastic wraps or containers. However, single-use plastics pose a significant environmental problem. Made from non-renewable petroleum resources, they take centuries to decompose. Improperly disposed single-use plastics end up in landfills, oceans, and waterways, causing harm to wildlife, polluting the environment, and entering the food chain. Consequently, there is a global movement to reduce single-use plastics consumption and promote sustainable alternatives. The alarming facts of India's plastic consumption are as follows

- The total plastic consumption in India was estimated to be 21 million tons in 2021 [1].
- The per capita plastic consumption in India was estimated to be 15 kg in 2021 [2].
- In 2021, India generated approximately 9.46 million tons of plastic waste, of which 43% was single-use plastic [3]. The most common single-use plastics used in India are plastic bags, straws, and bottles.

There are about 88,000 single-use plastic manufacturers in India, according to Kishore P. Sampat, president of the All India Plastics Manufacturers Association [4]. These manufacturers produce a

wide range of single-use plastic products, including plastic bags, straws, bottles, cups, and cutlery. As the demand for sustainable options grows, there is an increasing necessity for these manufacturers to explore and adopt alternative materials and products over time.

This white paper explores the research, commercial potential, and policy support for alternatives to single-use plastics. It begins by discussing the environmental impact of single-use plastics. It then examines the research that has been done on alternatives to single-use plastics and the commercial potential of these alternatives. There is a growing body of research on alternatives to single-use plastics. These alternatives include reusable bags, water bottles, straws, and utensils. These alternatives are made from materials that are biodegradable or compostable. They are also more durable than single-use plastics, which means that they can be used multiple times.

There is growing policy support for alternatives to single-use plastics. A number of countries have banned the use of single-use plastic bags, and other countries are considering similar bans. There are also a number of initiatives underway to promote the use of sustainable packaging. Finally, it summarizes on how to promote the use of alternatives to single-use plastics.

1.1 Single-Use Plastics Consumption & Curbing Consumption

SUPs encompass plastic products intended for one-time use before being discarded. SUPs find application in diverse areas, such as food packaging, straws, and bottles, posing a significant environmental challenge due to their detrimental effects on waterways, wildlife, and climate change. Due to their negative impact on ecosystems and human health, there is a growing global movement to reduce the consumption of single-use plastics and promote more sustainable alternatives, such as reusable items or materials that are biodegradable or compostable. Fortunately, a range of alternatives to SUPs exists, including reusable bags, water bottles, and straws. By embracing these alternatives, we have the opportunity to actively mitigate the environmental consequences associated with plastic pollution.

The consumption of plastic in India is expected to continue to grow in the coming years due to a number of factors, such as increasing urbanization, rising incomes, and changing lifestyles. The packaging industry is the largest consumer of plastic in India. Unfortunately, the economic value of 95% of packaging material is lost soon after its first use [5]. The various applications where the single-use plastics are used are listed as shown in Table 1, and Figure 1 shows the life cycle of the various commonly used SUPs.

Application	**Examples**
Shopping Bags	Lightweight plastic bags for carrying items
Beverage Containers	Plastic water bottles, soda bottles, juice bottles
Food Packing	Plastic wraps, bags, pouches, trays
Toiletries & Personal Care	Shampoo bottles, lotion bottles, cosmetics packing
Disposable Cups	Plastic cups for cold drinks
Food Storage Containers	Takeout containers, fast-food packing
Plastic Film & Wrappers	Snack Packing, candy wrappers
Beverage Lids	Lids for Coffee cups, soft drink cups
Personal Hygiene Products	Toothbrush, Razor, Plastic Ear Buds, Diapers, Sanitary Napkins
Condiment Packets	Ketchup packets, mayonnaise packets

Table 1: Applications and examples of SUPs

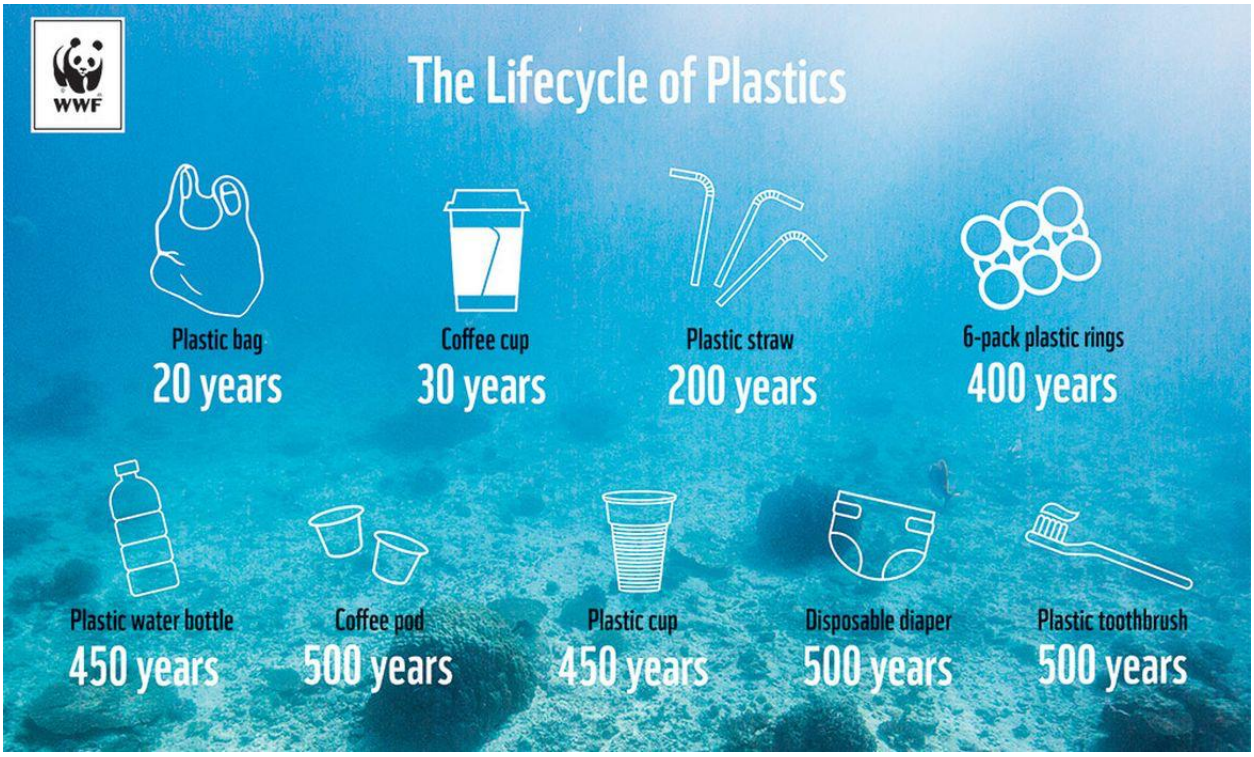


Figure 1: Life cycle of the Plastic in years before it degrades in the environment [6].

Research findings suggest that it is possible to significantly decrease the usage of single-use plastics by adopting alternative solutions. Plastic pollution could reduce by 80 percent by 2040 if countries and companies make deep policy and market shifts using existing technologies, according to a new report by the UN Environment Programme (UNEP) [7]. However, studies emphasize the possibility of substantial decreases in single-use plastics without completely eliminating their use. While it may be challenging to completely eliminate single-use plastics in certain contexts, the focus should be on identifying and implementing viable alternatives to minimize their overall impact.

India has propagated several regulatory measures to curb plastic consumption, and as per the latest Government announcement, the following measures were taken

- Plastic bag ban: In 2021, the Indian government banned the production, sale, and use of plastic bags thinner than 100 microns. This ban was implemented in phases, with the first phase starting on July 1, 2022[8].

- Prohibition on certain single-use plastic items: In 2022, the Indian government prohibited the production, sale, and use of 19 single-use plastic items, including straws, earbuds, and plastic cutlery. This ban came into effect on July 1, 2022 [8].
- Extended producer responsibility (EPR) scheme for plastic packaging: In 2022, the Indian government introduced an EPR scheme for plastic packaging. This scheme requires producers of plastic packaging to take responsibility for the collection and recycling of their products at the end of their life [8].

Considering the environmental impacts and the fact that consumption cannot be totally avoided, the need for finding and implementing alternative and sustainable technologies remains crucial. It is important to explore and invest in R&D activities that can lead to the development of innovative and eco-friendly alternatives to single-use plastics. These technologies can offer similar utility value to consumers while reducing the environmental impact associated with conventional single-use plastics.

1.2 Environmental impact of single-use plastics

The following facts shed light on the alarming issue of plastic pollution in the Ganges River and its detrimental impact on the Sundarbans, a UNESCO World Heritage Site. It is so alarming that immediate action is to protect these invaluable natural resources for future generations.

1. The Ganges River, one of the world's most sacred and iconic rivers, faces its share of plastic pollution challenges. Plastic waste from cities and towns along the river flows into the river, where it can harm wildlife, pollute water supplies, and contribute to climate change. It is estimated that 2,000 metric tons of plastic waste go into the Bay of Bengal every year. This is equivalent to dumping a garbage truck full of plastic into the river every hour. A recent study titled ‘Quantitative analysis of Microplastics along River Ganga’ revealed that The Ganga was found to be polluted with plastic waste, mainly single-use and secondary plastic products, with traces of 40 different types of polymers were found during analysis of which EVOH, Polyacetylene, PIP, PVC, and PVAL were predominant [9].

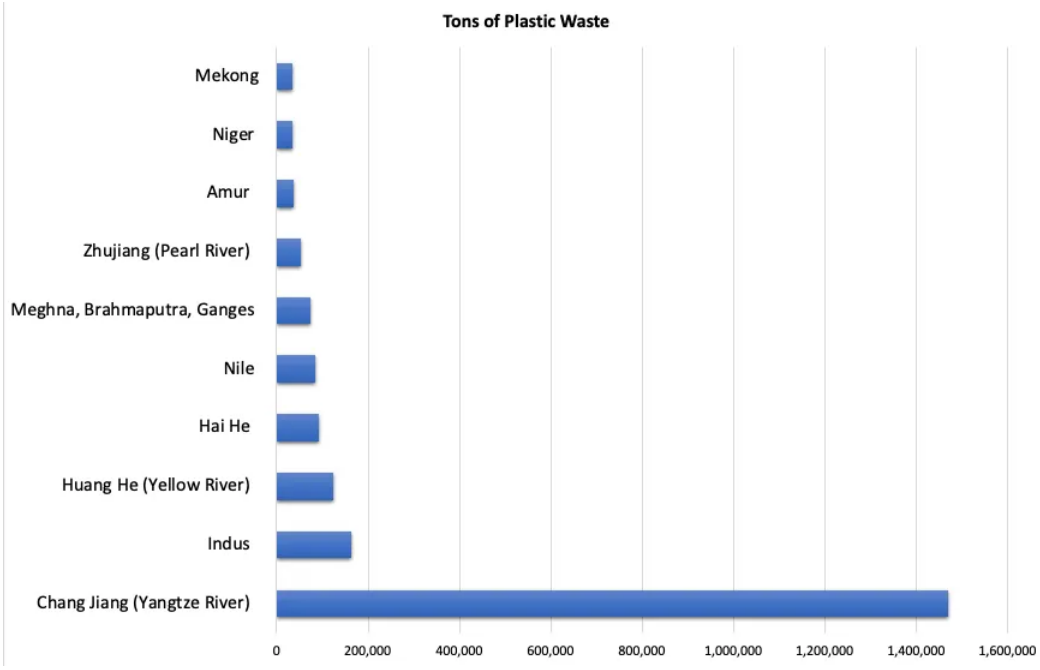


Figure 2: Top 10 rivers carrying plastic waste into the oceans. [10]

2. The Sundarbans is a UNESCO World Heritage Site and a major mangrove forest in India. The forest is home to a wide variety of wildlife, including tigers, dolphins, and crocodiles. A study by the World Wildlife Fund found that plastic pollution in the Sundarbans is a major threat to the forest's biodiversity. It has been observed that 4 million tonnes of microplastics have been discharged annually from various rivers of India and Bangladesh to Sundarban and the Bay of Bengal. [11].

2. Overview of alternatives to single-use plastics

India's bioplastics market was valued at $320.13 million in 2021. It is expected to reach $1060.77 million by 2027 at a CAGR (compound annual growth rate) of 22.1 percent [12].

1. Bioplastics are a type of plastic that is made from renewable resources, such as plants or algae. They are a potential alternative to conventional plastics, which are made from petroleum.

2. Biodegradable plastics are a type of bioplastic that can be broken down by microorganisms. This means that they can be composted or returned to the environment without harming it.
3. Oxo-degradable plastics are a type of plastic that is designed to break down into smaller pieces over time. However, these pieces are not biodegradable and can still harm the environment.

Bioplastics Materials:

1. Polylactic Acid (PLA): PLA is a bioplastic derived from renewable resources such as corn or sugarcane. It is commonly used in packaging, disposable cutlery, and food containers.
2. Polyhydroxyalkanoates (PHA): PHA is a bioplastic produced by microorganisms. It can be derived from plant oils or agricultural waste and is used in applications like packaging, agricultural films, and medical products.
3. Polybutylene Succinate (PBS): PBS is a bioplastic derived from succinic acid an d 1,4-butanediol, often obtained from plant-based sources. It is used in packaging films, disposable cutlery, and agricultural mulch films.

Biodegradable Materials:

1. Chitosan: Chitosan is a natural polymer derived from the shells of crustaceans. It has antimicrobial properties and can be used to make films, coatings, and foams for food packaging.
2. Gelatin: Gelatin is a protein derived from animal skin and bones. It is used to make films and coatings for food packaging.
3. Pectin: Pectin is a natural polymer found in fruits and vegetables. It can be used to make films and coatings for food packaging.
4. Starch: Starch is a carbohydrate found in plants. It can be used to make films and coatings for food packaging.
5. Cellulose: Cellulose is a natural polymer found in plants. It can be used to make films and coatings for food packaging.

Oxo-degradable Plastics:

Oxo-degradable plastics are conventional plastics that contain additives that promote degradation under certain conditions, such as exposure to oxygen and heat. However, their environmental impact and claims of complete biodegradability are subject to debate. It is important to note that oxo-degradable plastics are not considered a sustainable solution for plastic waste.

Bioplastic standards are set by various organizations to ensure that bioplastics meet certain requirements. These standards can help to ensure that bioplastics are safe for the environment and that they are not misleadingly labeled. The regulation of bioplastics is still in its early stages. However, it is important to develop regulations that will ensure that bioplastics are safe and that they do not harm the environment. The future of bioplastics is promising. Bioplastics have the potential to reduce our reliance on petroleum and to help us to reduce our environmental impact. However, more research is needed to improve the performance of bioplastics and to develop more sustainable production methods.

There are many traditional alternative materials to single-use plastics. Some of the most common include:

1. Paper: Paper is a renewable resource that can be used to make a variety of single-use items, such as bags, plates, and cups.
2. Wood: Wood is another renewable resource that can be used to make a variety of single-use items, such as utensils, straws, and bowls.
3. Bamboo: Bamboo is a fast-growing grass that is strong and durable. It can be used to make a variety of single-use items, such as straws, utensils, and plates.
4. Metal: Metal is a long-lasting material that can be recycled. It can be used to make a variety of single-use items, such as water bottles, utensils, and straws.
5. Glass: Glass is a recyclable material that is non-toxic. It can be used to make a variety of single-use items, such as water bottles, cups, and bowls.

The following image shows the alternative to single-use plastics that can be replaced by traditional alternatives (Figure 3).

Figure 3: Traditional alternatives to SUPs [13]

In this white paper, we explore the advanced materials that are eco-friendly that can potentially replace single-use plastics where their use is inevitable. We shall also share a few success stories of how they have implemented a road map to transit to eco-friendly alternatives to single-use plastics.

2.1 Researchers and institutions driving innovation in India

The table below presents recent research conducted by researchers on alternatives to single-use plastics, showcasing their findings and comprehensive recommendations based on their exhaustive research.

Authors	Area of Study	Result	Reference
Krishnamurthy, A., & Amritkumar, P. (2019).	Poly Lactic Acid	The results showed that the films had good tensile strength, elongation at break, and water resistance. The films were also biodegradable and non-toxic. The results suggest that the bioplastic films could be used as a sustainable alternative to conventional plastics.	Synthesis and characterization of eco-friendly bioplastic from low-cost plant resources [14].
Vanapalli, K. R., Bhattacharya, J., Samal, B., Chandra, S., Medha, I., & Dubey, B. K. (2021).	Silicone	The co-pyrolysis of biomass and single-use plastics can result in synergistic or inhibitory effects on the thermal behavior and char characteristics of the resulting products. The type of effect depends on the specific biomass and plastic materials used, as well as the pyrolysis conditions. The results suggest that co-pyrolysis can be used to produce high-value products from biomass and plastic waste. The authors suggest that co-pyrolysis can be used to produce high-value products from biomass and plastic waste.	Inhibitory and Synergistic Effects on Thermal Behaviour and Char Characteristics During the Co-Pyrolysis of Biomass and Single-Use Plastics[15].
Vijayan, S. P., Aparna, S., &	Beeswax	The addition of beeswax to UV-curable linseed oil based coatings	Effect of Beeswax on hydrophobicity,

Sahoo, S. K. (2023).		improved the hydrophobicity, moisture resistance, and transparency of the coatings. The authors suggest that the coatings could be used as a sustainable alternative to conventional coatings for paper packaging.	moisture resistance and transparency of UV curable linseed oil based coating for compostable paper packaging[16].
Dugvekar, M., & Dixit, S. (2023).	Coir Fiber	The authors concluded that the mercerization treatment is an effective way to improve the thermal, structural, and morphological properties of coir fiber–reinforced composites. The improved properties of the mercerized composites make them a potential candidate for a variety of applications, such as automotive, aerospace, and marine.	Thermal, structural, and morphological examination of mercerized coir fiber–reinforced composites[17].
Gupta, H., Kumar, H., Gehlaut, A. K., Singh, S. K., Gaur, A., Sachan, S., & Park, J. W. (2022).	Coir Fiber	The results of this study show that bio-composite films obtained from coconut coir and groundnut shell are a promising alternative to commercial plastic films for food packaging applications. The films have good mechanical, physical, and barrier properties, and they	the Preparation and characterization of bio-composite films obtained from coconut coir and groundnut shells for food packaging [18].

		also have good antibacterial activity.	
Kiran V, G., Varsha A, K., M, V., Govindaraj, V., M, A., N, V., . . . Chezhiyan, P. (2022)	Bioplastics	The results suggest that banana peel starch-based bioplastic could be a viable alternative to petroleum-based plastics in the manufacture of intravenous tubes	Synthesis and characterization of banana peel starch-based bioplastic for intravenous tubes preparation [19].
Mahansaria, R., Bhowmik, S., Dhara, A., Saha, A., Mandal, M. K., Ghosh, R., & Mukherjee, J. (2020)	Bioplastics, Desalination	The study by Mahansaria et al. (2020) demonstrated the successful enhancement of PHBV production using Halogeometricum borinquense, characterized the properties of the produced bioplastic, and explored the potential for desalination of the bioreactor effluent. These findings contribute to the understanding of PHBV production, its characterization, and the sustainable management of byproducts in the process.	Production enhancement of poly(3-hydroxybutyrate-co-3-hydroxyvalerate) in Halogeometricum borinquense, characterization of the bioplastic, and desalination of the bioreactor effluent [20].
Nida, S., Moses, J. A., & Anandharamak	Sustainable packaging	The study by Nida, Moses, and Anandharamakrishnan (2021) highlights the potential of sugarcane bagasse as a raw	3D printed food package casings from sugarcane bagasse: A

rishnan, C. (2021)		material for 3D printed food package casings. The research demonstrates the feasibility of waste valorization and offers a sustainable solution for food packaging by utilizing an abundant agricultural byproduct.	waste valorization study [21].
Parvathy, P. A., & Sahoo, S. K. (2021)	Sustainable coatings	The study develops a hydrophobic, moisture-resistant, and bio-renewable paper coating derived from castor oil-based epoxy methyl ricinoleate with repulpable potential. The coating exhibited favorable properties for various paper applications while being repulpable and environmentally friendly.	Hydrophobic, moisture resistant and bio-renewable paper coating derived from castor oil-based epoxy methyl ricinoleate with repulpable potential [22].
Preethi, R., Moses, J. A., & Anandharamakrishnan, C. (2021)	Active packaging	The study by Preethi, Moses, and Anandharamakrishnan (2021) successfully developed a biopolymeric film incorporated with anacardic acid for active packaging applications. The film exhibited antimicrobial and antioxidant properties, demonstrating its potential to extend the shelf life	Development of anacardic acid incorporated biopolymeric film for active packaging applications [23].

		and enhance the safety of food products	
Shanmathy, M., Mohanta, M., & Thirugnanam, A. (2021)	Bioplastics	The study develops biodegradable bioplastic films using taro starch reinforced with bentonite. The films exhibited improved mechanical and barrier properties compared to pure taro starch films.	Development of biodegradable bioplastic films from taro starch reinforced with bentonite [24].
Sonawane, P., Panchal, A., Naik, S., Mundaye, B., & Padalia, U. (2021)	Bioplastics	The study explores the use of potato starch-based bioplastic as an alternative packaging material. The researcher successfully developed a potato starch-based bioplastic as an alternative packaging material. The bioplastic exhibited favorable mechanical properties, barrier properties, and biodegradability, indicating its potential as a sustainable packaging option.	Potato starch-based bioplastic as alternative packaging materials [25].
Vanapalli, K. R., Bhattacharya, J., Samal, B., Chandra, S., Medha, I., & Dubey, B. K. (2021)	Composite materials, Soil application	The study focuses on the optimized production of a composite material made from single-use plastic and eucalyptus wood char for soil application. However, the study was conducted on a small scale, long-term effects and commercial feasibility not investigated.	Optimized production of single-use plastic-eucalyptus wood char composite for application in soil [26].

2.2 List of Institutes that are involved in the Research in the area of Alternatives to the Single Use Plastics.

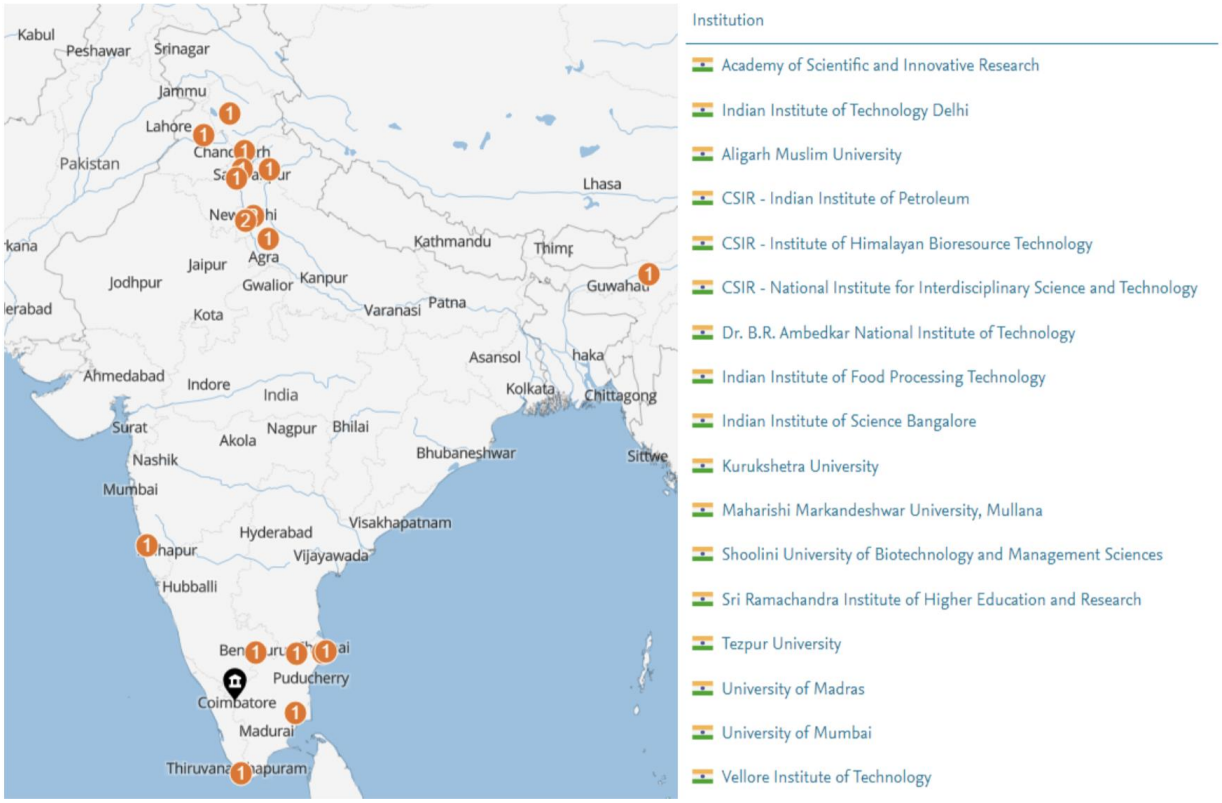


Figure 4: Geographic location of research institutions in India

2.3 Funding agencies supporting research and development

The list of funding agencies that supported the research activities of alternatives to single-use plastics are as mentioned below.

1. Department of Science and Technology (DST), Ministry of Science and Technology, India

2. Science and Engineering Research Board, India
3. Birla Institute of Technology and Science, Pilani
4. Council of Scientific and Industrial Research (CSIR), India
5. Deanship of Scientific Research, King Saud University
6. Indian Council of Medical Research (ICMR), India
7. Kurukshetra University
8. Ministry of Education (MoE), India
9. Ministry of Science, ICT and Future Planning
10. University Grants Committee (UGC), India
11. VIT University

2.4 Current Research Areas in India

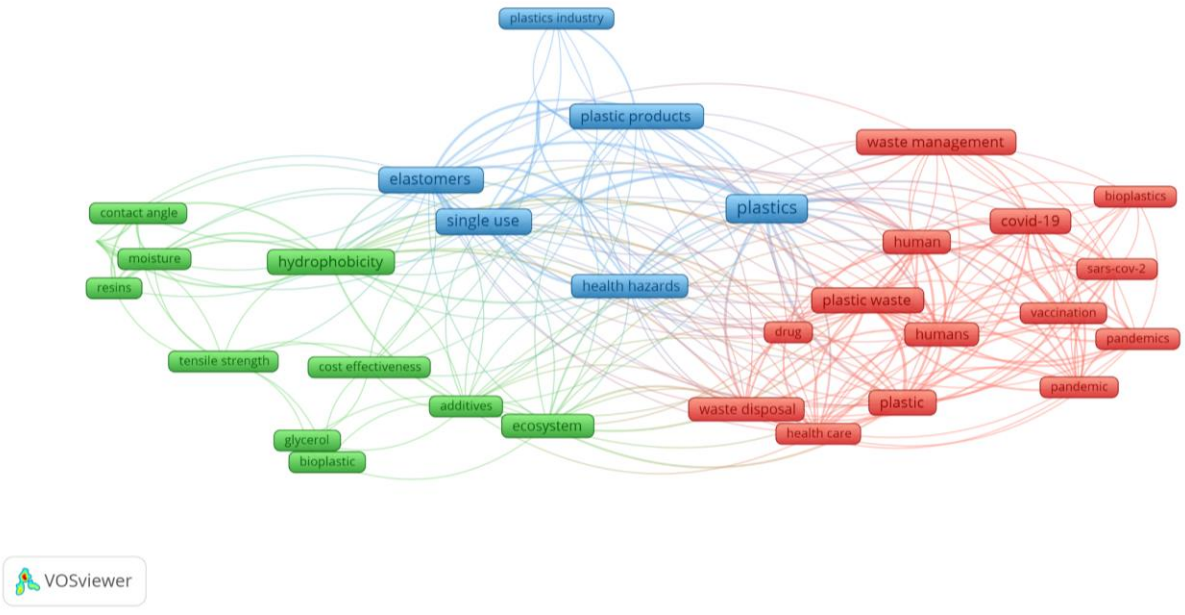


Figure 5: Image created using VOSViewer from the SCOPUS data

Current research in the field of alternatives to single-use plastics can be categorized into three main areas: characteristics of alternative materials, waste management regarding single-use

plastics, and the development of alternative products. Researchers are focusing on various attributes of interest, including resins, tensile strength, hydrophobicity, elastomers, cost-effectiveness, health hazards, and waste disposal.

3. Current Market Scenario in Sustainable Alternative to Single-Use Plastics

Analyzing the current scenario of available, viable market alternatives, their scalability, cost-effectiveness, technology availability for entrepreneurs, and patents is indeed essential to understand the gap in the sustainable alternatives to the single-use plastics market.

The existing sustainable alternatives to single-use plastics are crucial to determine the breadth and depth of the market. This includes exploring materials such as bioplastics (e.g., PLA, PHA), compostable materials, paper-based alternatives, and innovative packaging solutions.

The scalability potential of alternative materials and technologies is important to assess their ability to meet market demands. Factors such as raw material availability, production capacity, and compatibility with existing manufacturing processes need to be evaluated.

The cost-effectiveness of sustainable alternatives compared to traditional single-use plastics is vital. Considerations should include the costs associated with sourcing raw materials, manufacturing processes, transportation, and end-of-life management.

Analyzing the existing patents in the field of sustainable alternatives to single-use plastics provides insights into the level of innovation, competitive landscape, and potential barriers for new entrants. It helps determine if there is a need for licensing or collaboration to access patented technologies.

Understanding consumer preferences, behaviors, and their willingness to adopt sustainable alternatives is crucial for market viability. Analyzing market research, consumer surveys, and

trends can provide insights into the demand for sustainable alternatives and potential market gaps.

By conducting a comprehensive analysis of these factors, stakeholders can gain a clearer understanding of the current scenario, identify gaps and opportunities, and make informed decisions regarding technology development, research and development investments, and policy making in the sustainable alternatives to single-use plastics industry.

According to a report by the World Economic Forum, India is the third-largest consumer of plastic straws in the world. In 2020, the country consumed an estimated 12 billion plastic straws. This number is expected to grow to 15 billion by 2025. The Indian government has taken steps to reduce the use of plastic straws. In 2022, the government banned the manufacture, sale, and use of single-use plastic straws. The ban has been met with mixed reactions from businesses and consumers.

Beverage manufacturers in India use around 6 billion straws annually and “the domestic capacity for paper straws is zero,” said Praveen Aggarwal, CEO of Action Alliance for Recycling Beverage Cartons, an association of leading beverage makers. At present, Indian manufacturers of biodegradable plastic only have the capacity to meet up to 8% of demand and beverage companies. Hence a review of the present technologies available is required to scale up to the demands of the market.

3.1 Current Market Players in the Alternatives to Single Use Plastics

Retro Straw

Retro Straws is to change the perception of people and businesses and inspire them to live an environmentally conscious life without disrupting the ecological balance. Retro Straws intends to completely replace plastic straws, support agricultural communities and increase the quality of life for all living forms on the planet. are a bio-degradable and compostable alternative designed

to reduce the usage of single-use plastic straws. Retro Straws was created to provide a plant-based, organic option to the dangerous plastic straws that pollute our environment. They are completely plant-based and contain no animal byproducts. Retro Straws intend to inspire a sense of responsibility in the young generation and help businesses adopt a safer alternativeThe brand is a social start-up by a group of young millennial entrepreneurs and is based in Telangana, India.

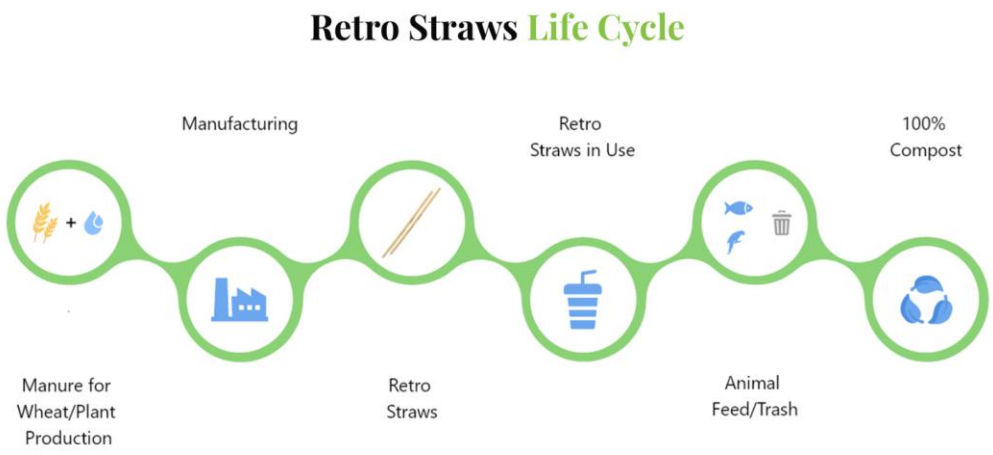


Figure 6: Life Cycle of Retro Straws

Evlogia Eco Care

Evlogia Eco Care is a Bangalore-based startup founded in 2018, that develops eco-friendly and healthy innovations for daily use. Their flagship product is the Leafy Straw, a biodegradable straw made from fallen coconut palm leaves. Leafy Straws are certified by the FDA and ISO, and they are helping to create jobs in rural South Asia. Evlogia Eco Care is a company that is committed to sustainability and social responsibility. Evlogia Eco Care has won several awards for its innovation and sustainability, including the 2019 Green Good Design Award and the 2020 INDEX: Award. The company is committed to giving back to the community, and it has partnered with several organizations to promote sustainability and social responsibility. Evlogia Eco Care owns a patent for the product and process of making Leafy straws from coconut palm leaves. Evlogia holds a patent that covers the unique method of using a bonding agent to keep the straw in its rolled

shape. This patent gives Evlogia Eco Care a competitive advantage in the market, and it helps to ensure that the Leafy Straw is a sustainable and environmentally friendly product. The patent number for the Leafy Straw is 309356

Sunbird Straws

Figure 7: EcoFriendly Sunbird Straws

Sunbird Straws is a Bengaluru-based company that manufactures and sells eco-friendly straws made from coconut leaves. The company was founded in 2017 by Saji Varghese, an associate professor at Christ University. Sunbird Straws has received several awards, including the Shreshta Udyami Guru Puraskar 2020 from the Entrepreneurship Development Institute of India (EDII) and the First Position at Start-Up Launchpad by the ASSOCHAM, New Delhi. Sunbird Straws offers a variety of eco-friendly straws made from coconut leaves. The straws are available in a variety of sizes and lengths, and they can be used with hot or cold beverages. Sunbird Straws offers a number of benefits over traditional plastic straws. Coconut leaf straws are biodegradable, so they do not contribute to plastic pollution. They are also sustainable, as they are made from a renewable resources. Additionally, coconut leaf straws are strong and durable, so they can be

reused multiple times. Sunbird Straws is committed to sustainability. The company sources its coconut leaves from sustainable farms, and it uses a water-saving manufacturing process. Sunbird Straws is also a certified B Corporation, which means that it meets high standards of social and environmental performance, accountability, and transparency. Sunbird Straws has had a positive impact on the environment and the community. The company has helped to reduce plastic pollution, and it has created jobs for women in rural areas. Sunbird Straws is an example of how businesses can make a positive impact on the world while also being profitable. Sunbird Straws is a leading provider of eco-friendly straws. The company offers a variety of benefits, including biodegradability, sustainability, and strength.

EcoVise Solutions

Dr. Devasena, a passionate sustainability researcher from India, established EcoVise Solutions to develop sustainable straws using Phragmites karka, an abundant reed often burned as a weed. These reusable straws have a year-long lifespan, are durable, and can be repurposed as bag handles. Dr. Devasena aims to change perceptions, reduce reliance on single-use plastics, and create economic opportunities for farmers and entrepreneurs. By harnessing the potential of this overlooked plant, she envisions a greener future for India.

Figure 8: Phragmites Karka made into straws.

Dinearth - Eco-Friendly Tableware

Since 1998, Abhinav Industries has been dedicated to providing top-notch packaging and dining solutions to the food and Quick Service Restaurant (QSR) industry in India. Dinearth represents a new era of reusable and recyclable tableware, aiming to create a sustainable and green future. Our goal is to build a smart, safe, and pure Earth where we can coexist harmoniously with nature. We strive to contribute to the better health of consumers and the preservation of our environment. By altering our thinking and embracing Dinearth, we seek to bring about a positive change in our way of life, making the environment a happier and healthier place to thrive.

Dinearths tableware products are made from sugarcane bagasse, a non-food renewable resource obtained from the fiber that remains after the sugarcane stalks are processed. It is molded into robust and visually appealing packaging products. Dinearth's sugarcane-based tableware is certified compostable and biodegradable, further enhancing its eco-friendliness.

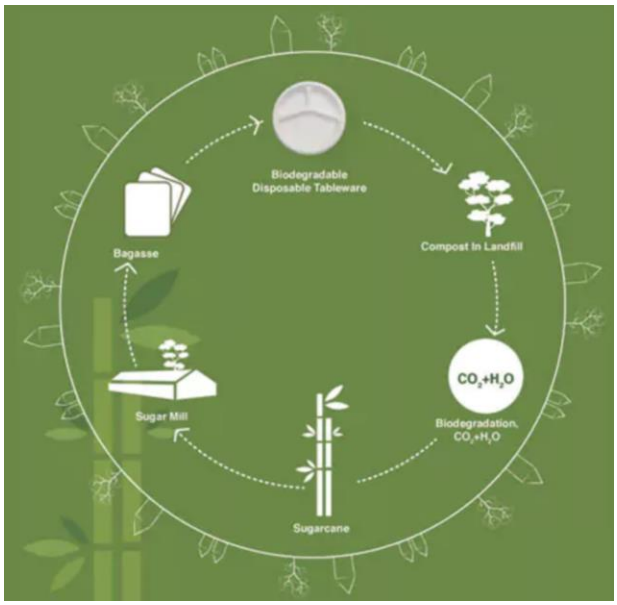


Figure 9: Lifecycle of Dinearth Sugarcane based alternative to SUPs.

Key Features of Dinearth

- Crafted from 100% renewable natural plant fiber.
- Completely devoid of plastic coating.
- Food-safe and non-toxic.

- Free from heavy metals and other harmful chemicals.
- Causes no environmental pollution.
- No presence of cancer-causing agents.
- Microwave and freezer friendly.
- Resistant to water and oil.

Plasto Manufacturing Company

Bio-Plastobag is an acclaimed brand under Plasto Manufacturing Company, a prominent manufacturer of certified compostable bags in India. With expertise in manufacturing, compounding, and printing, Plasto Manufacturing Company has established itself as a leader in the industry. The company has a rich history, starting as a family business in 1968 during the early stages of the plastic industry. Over the years, it has evolved and adapted to market demands and technological advancements, becoming a successful producer of polyethylene, polypropylene, and biopolymer compounds. Bio-Plastobag, trusted by numerous companies and the general public, serves global markets and caters to various industries requiring compostable plastic products. It provides an innovative solution to the plastic pollution problem by utilizing bio-polymers, offering the same convenience as regular plastic while conserving fossil and tree resources. After use, Bio-Plastobag can be composted, decomposing into carbon dioxide (CO2) and water with the help of natural microorganisms, leaving no harmful effects behind. The compostable films are available in various widths ranging from 1 inch to 100 inches, with thickness options between 10 microns and 400 microns. Notably, each bag features a unique dynamic QR code, a first-of-its-kind initiative in India, ensuring product genuineness. The company serves a global client portfolio spanning retail sectors, textile industries, religious institutions, airports, hospitals, and online partners.

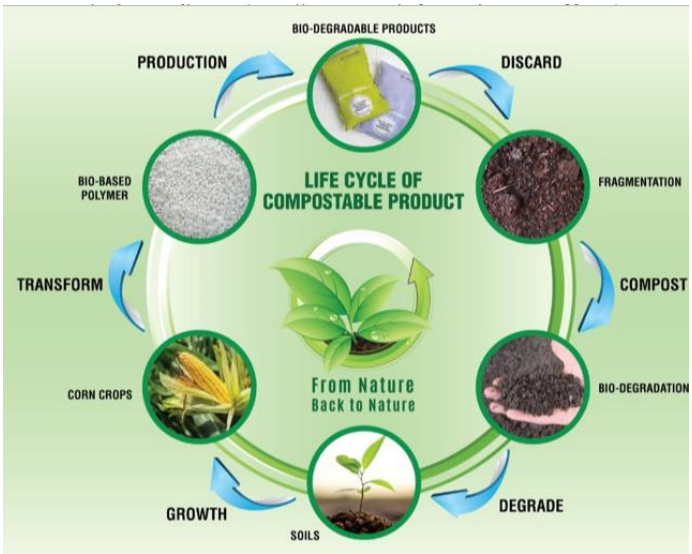


Figure 10: Lifecycle of Compostable Product

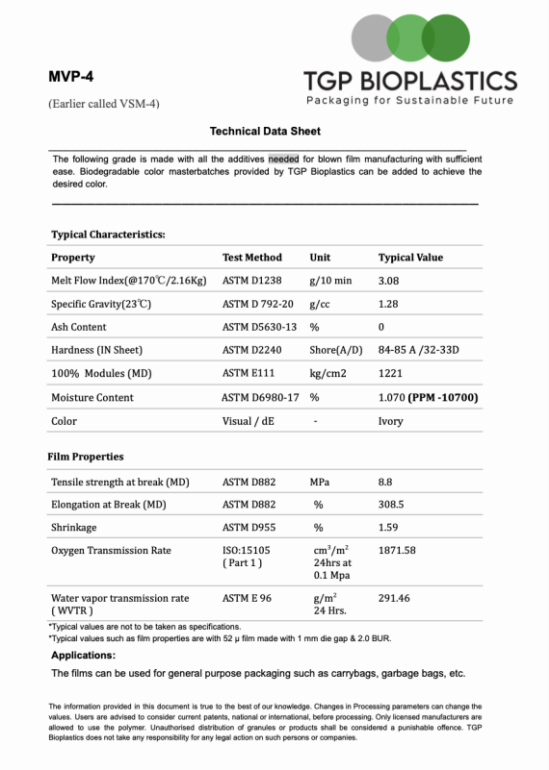
JC Bioplastics

Founded in September 2018, JC BIOPLASTIC is a company dedicated to supplying 100% Biodegradable and Compostable Plastic Products. Our mission, called Paryavarna Raksha, meaning "save environment," aims to address the environmental challenges we face today. The increasing occurrence of natural disasters serves as a reminder of the damage we have caused to our planet. JC BIOPLASTIC offers bioplastic made from gluten derived from starch sources like corn and other agricultural products. Our products are completely environmentally friendly, being 100% biodegradable and compostable plastics.

TGP Bioplastics

TGP Bioplastics specializes in the production of plastic granules, serving as essential raw materials for packaging industries. These granules are transformed into films of various sizes and shapes, offering an eco-friendly alternative to flexible retail packaging like carry bags, garbage bags, e-commerce packaging, and industrial wrappings. Targeting the extensive Indian flexible packaging industry, estimated to be over 3.9 million metric tonnes, TGP Bioplastics aims to capture a significant market share. In its inaugural year, the company plans to acquire at least 10% of the current market, equivalent to Rs 24 crore. With a projected compound annual growth rate (CAGR) of 22.1% in the biodegradable market, TGP Bioplastics aims to replace a substantial

portion (at least 60%) of imported raw materials by 2025. The composite material developed by TGP Bioplastics combines Thermoplastic-Starch (TPS) and glycerine, incorporating chemical modifications to enhance strength while ensuring cost-effectiveness. The composition primarily consists of more than 50% corn starch sourced from manufacturing plants within India, along with glycerine. By procuring raw materials from Maharashtra and Karnataka, TGP Bioplastics aims to reduce logistical costs and carbon footprints associated with transportation. The company is committed to providing sustainable and affordable packaging alternatives, contributing to the preservation of our planet. TGP Bioplastics has garnered significant support from various governmental agencies, securing grants from the Department of Science & Technology (DST), NITI Aayog, and the United Nations. Additionally, the Technology Development Board (TDB) has provided a subsidized loan of Rs 1.15 crore to further aid the company's endeavors. To expand operations and cater to domestic and international markets, TGP Bioplastics plans to establish a manufacturing facility with an annual capacity of 800 metric tonnes. You can find the datasheet for more information at [27].



MVP-4

(Earlier called VSM-4)

TGP BIOPLASTICS
Packaging for Sustainable Future

Technical Data Sheet

The following grade is made with all the additives needed for blown film manufacturing with sufficient ease. Biodegradable color masterbatches provided by TGP Bioplastics can be added to achieve the desired color.

Typical Characteristics:

Property	Test Method	Unit	Typical Value
Melt Flow Index(@170℃/2.16Kg)	ASTM D1238	g/10 min	3.08
Specific Gravity(23℃)	ASTM D 792-20	g/cc	1.28
Ash Content	ASTM D5630-13	%	0
Hardness (IN Sheet)	ASTM D2240	Shore(A/D)	84-85 A /32-33D
100% Modules (MD)	ASTM E111	kg/cm2	1221
Moisture Content	ASTM D6980-17	%	1.070 **(PPM -10700)**
Color	Visual / dE	-	Ivory

Film Properties

Tensile strength at break (MD)	ASTM D882	MPa	8.8
Elongation at Break (MD)	ASTM D882	%	308.5
Shrinkage	ASTM D955	%	1.59
Oxygen Transmission Rate	ISO:15105 (Part 1)	cm^3/m^2 24hrs at 0.1 Mpa	1871.58
Water vapor transmission rate (WVTR)	ASTM E 96	g/m^2 24 Hrs.	291.46

*Typical values are not to be taken as specifications.
*Typical values such as film properties are with 52 µ film made with 1 mm die gap & 2.0 BUR.

Applications:

The films can be used for general purpose packaging such as carrybags, garbage bags, etc.

The information provided in this document is true to the best of our knowledge. Changes in Processing parameters can change the values. Users are advised to consider current patents, national or international, before processing. Only licensed manufacturers are allowed to use the polymer. Unauthorised distribution of granules or products shall be considered a punishable offence. TGP Bioplastics does not take any responsibility for any legal action on such persons or companies.

Figure 11: Material Data Sheet of TGP Bioplastics

Green Tech Bio Products

Green Tech Bio Products, based in Coimbatore, India, is a prominent manufacturer and exporter of a diverse range of environmentally-friendly products. Established in 2019, the company is at the forefront of producing water-soluble films, laundry bags, PVA resin, and more. With a growing global consciousness towards sustainability, the demand for water-soluble plastics has increased across various industries. Green Tech Bio Products takes pride in being India's sole manufacturer of hot-water soluble biodegradable pellets, known as GreenPlastTM. These innovative pellets are 100% plastic-free and do not generate microplastics like traditional polyethylene (PE) or polypropylene (PP) bags. Regarding disposal, the bags or films can be dissolved in cold or hot water (above 70°C) within a short time, typically less than 5 minutes. Alternatively, if not dissolved, the bags and films can be composted under suitable conditions and degrade by 90% within 180 days. Green Tech Bio Products remains committed to offering sustainable solutions contributing to a greener environment.

Figure 12: PVA Resin Manufactured by Greenplast

Banyan Nation: Driving Circular Economy Through Vertically Integrated Plastic Recycling

Banyan is a pioneering company within India's plastic recycling industry, dedicated to vertically integrated operations that empower global brands to incorporate higher amounts of recycled plastic into their products. Their focus lies in promoting a circular economy by converting post-consumer and post-industrial plastic waste into premium recycled granules through proprietary plastic cleaning technology and an innovative data intelligence platform. Banyan's goal is to create a sustainable and efficient plastic recycling ecosystem by integrating informal recyclers into their supply chain and assisting municipalities with waste management. The company's unique plastic cleaning technology effectively eliminates inks, coatings, and contaminants from plastic waste using eco-friendly detergents and solvents. This process results in high-quality recycled granules known as Better Plastic™, which rival virgin plastic in terms of quality and performance. Banyan's technology represents a significant advancement in India's informal and low-tech plastic recycling sector, enabling the production of recycled plastic that closely resembles virgin plastic. As a leader in circular economy practices, Banyan has successfully implemented closed-loop recycling initiatives with prominent companies in various industries. By collaborating with India's top automotive company, Banyan facilitated the production of new bumpers using discarded ones, while partnering with a global cosmetics company allowed them to create new bottles from discarded ones. These initiatives exemplify Banyan's commitment to circularity and its potential for expansion into other industries. Through the integration of mobile, cloud, and Internet of Things (IoT) technologies, Banyan has effectively incorporated thousands of informal sector collectors into its supply chain, ensuring a consistent supply of post-consumer and post-industrial plastic waste for recycling. Additionally, their data intelligence platform goes beyond supply chain integration to support cash-strapped municipalities in optimizing waste management. By providing valuable insights into waste flows within cities, Banyan's platform enables data-driven approaches to enhance waste management practices and make them more efficient and economically viable.

BioGreen Packaging

BioGreen Packaging is a renowned industry leader specializing in the provision of bags and films designed for the collection of organic waste, facilitating composting, and offering biodegradable alternatives for landfill sites. The company's primary objective is to prevent organic waste from entering landfills. Unlike traditional plastic bags, BioGreen bags incorporate biodegradable additives into conventional plastic, enabling them to biodegrade. Soil micro-organisms consume the biodegradable plastic, transforming it into organic matter such as water, CO2, CH4, and HUMUS. As a result, our bags can be safely used for composting alongside organic waste at municipal composting facilities. At BioGreen Packaging, we strictly adhere to international and Indian standards for testing biodegradable plastics, ensuring the production of world-class biodegradable and compostable plastics. Our innovative technology allows us to manufacture exceptional Biodegradable Plastic Products. BioGreen bags fully disappear in landfills and sewage sludge once they have fulfilled their purpose. Committed to our mission, our dedicated team focuses solely on the production of certified compostable and biodegradable bags and films.

BioGreen Packaging's founder, Subash Puri, firmly believes that certified compostable and biodegradable bags and films will soon become indispensable in resolving food waste separation challenges, especially with the expansion of "Zero Waste" initiatives nationwide.

Over the years, the BioGreen brand has gained a strong reputation for delivering top-quality certified biodegradable/compostable bags to consumers and businesses across the country. We work closely with local governments to establish effective food waste separation programs and educate consumers about the advantages of diverting food waste from landfills. BioGreen bags play a crucial role in the collection of organic waste for composting, contributing to waste diversion from landfills through their biodegradable and compostable properties.

Venus Biopack

Venus Biopack is a company that has high-tech research and development enterprise with leading technology, specializing in providing compostable raw materials and products, such as

compostable films, compostable bags, compostable cups, tableware, and other green products, with healthy, non-toxic, pollution-free and other characteristics.

The future of our world depends on the immediate reduction of plastic in our oceans. With innovation, education, and widespread adoption, we can significantly reduce the amount of plastic found in single-use products and on our planet.

Natures Bio Plastics

It is founded by environmental entrepreneurs. It Supply Biodegradable Plastic Materials & Compostable Bags like Biodegradable Bags / Compostable Bags, Biodegradable Covers, Compostable Covers, Garbage Covers, Stretch Film Rolls, Biodegradable Packaging, Eco-friendly Boxes, and Cutlery, More

Plastobags

Plastobags is an Indian company that specializes in manufacturing biodegradable and compostable bags and packaging materials. They offer a wide range of products made from bioplastics, including shopping bags, garbage bags, and food packaging.

Earthsoul India

Earthsoul India is a manufacturer of biodegradable and compostable products made from agricultural waste. They produce bioplastics under the brand name "Earthware" and offer a variety of products like plates, bowls, cups, and cutlery.

Bio-Lutions

Bio-Lutions is an Indian company that focuses on sustainable packaging solutions. They produce biodegradable and compostable packaging materials made from agricultural waste fibers. Their products include trays, plates, bowls, and other packaging solutions.

Natur-Tec India

Natur-Tec India is a manufacturer of bioplastics and compostable products. They offer a wide range of biodegradable and compostable resins and films that are used in packaging applications, agriculture, and other industries.

Biogeen Biotech

Biogreen Biotech is working towards sustainable packaging and alternatives for single-use plastic. Our products are derived from renewable resources such as corn starch, vegetable waste, sugarcane bagasse, and recycled ocean plastic. We as a company are looking for the betterment of our environment. These products are 100% compostable, biodegradable, and the most sustainably sourced products. We are creating an ecosystem where biogreen provides a solution for a sustainable future for humankind.

3.2 Success Stories in India

Flipkart Un-Plastic Collective Initiative

Flipkart's collaboration with WWF India under the Un-Plastic Collective (UPC) initiative aimed to address the issue of plastic leakage. The partnership involved multiple stakeholders working together voluntarily to drive corporate action and find solutions to tackle plastic waste. The focus was on promoting circularity and developing innovative business models in the plastic packaging sector. By leveraging the collective voice of various stakeholders across the value chain, the collaboration sought to create a positive impact and drive sustainable change in the industry. The Flipkart demonstrates a success story, and their journey towards sustainability also gives us wisdom for the other industry players for their transition and the challenges that one must endure during the process. It can also help in addressing the policy & regulation gap that can drive the future toward sustainability. The journey of Flipkart’s journey towards sustainable packing started in March 2019, and the timeline of adoption of the various alternatives and the milestones achieved is shown in the following chart.

March 2019

The packaging team **kicks off the design and development process** to scout for options to reduce and reuse packaging, replace single-use plastic, and recycle plastic waste generated in the supply chain to ensure **zero waste to landfill** across all Flipkart operations

December 2019

Shredded paper, 2-ply wraps, and other alternative materials replaced plastic in all our packaging filler materials

February 2020

Replaced plastic security bags with recyclable paper bags customised for e-commerce deliveries

May 2020

Single-use plastic eliminated by 50% in all shipments fulfilled by Flipkart. Replaced all single-use plastic for the state of Maharashtra

June 2020

National EPR authorisation received by Flipkart as a Producer/Brand Owner. Flipkart, compliant with recycling norms across India, starts **working with recyclers to divert all plastic waste generated away from landfills**

August 2020

Flipkart **introduces No-Package Shipping.** Starts working with sellers and suppliers to eliminate the need for outer packaging

December 2020

Single-use plastic eliminated by 56%. The sustainable packaging program expanded across Karnataka, Tamil Nadu, Telangana and Andhra Pradesh

January 2021

61% reduction achieved with sustainable packaging introduced in Haryana

May 2021

15% of products shipped without secondary packaging under the 'No Package Shipping' program. **96% of customer shipments from fulfilment centres (FCs) shipped in Sustainable Packaging.**

June 2021

Stopped all fresh procurement of single-use plastic materials for FCs.

July 2021

Flipkart achieved **the milestone of 100% elimination of single-use plastic** in its own supply chain covering **more than 70 facilities across India.**

September 2021

Marketplace seller adoption for **sustainable packaging reached 75%+.** It began with targeting **70 hubs** in the state of Maharashtra and today it covers **700+ hubs across the country**.

Figure 13: Journey of Sustainable Packing at Flipkart

Figure 14: Alternative packing material used by Flipkart

The challenges faced by Flipkart in the transition to sustainable packaging:

- Limited alternatives: There were limited like-to-like alternatives available in the market to replace plastic. This meant that Flipkart had to test a number of different materials and designs before finding one that was suitable for their needs.
- Cost: The cost of sustainable packaging can be higher than traditional packaging. This is because sustainable materials are often more expensive to produce and may require more specialized manufacturing processes.
- Compatibility: Sustainable packaging may not be compatible with existing packaging machinery. This can lead to additional costs for modifying or replacing machinery.
- Training: Employees may need to be trained on how to handle and use sustainable packaging. This can be a challenge, especially if the packaging is different from what they are used to.
- Consumer acceptance: Customers may not be willing to pay more for products that are packaged in sustainable materials. This can make it difficult for businesses to adopt sustainable packaging without losing sales.

Despite these challenges, Flipkart has made significant progress in its transition to sustainable packaging. They have developed a number of innovative solutions that have allowed them to reduce their environmental impact while still maintaining high standards of quality and customer service.

Here are some of the ways that Flipkart has overcome these challenges:

- Innovation: Flipkart has been innovative in its approach to sustainable packaging. They have developed a number of new materials and designs that are both sustainable and cost-effective.
- Partnerships: Flipkart has partnered with a number of suppliers and manufacturers to help them develop and implement their sustainable packaging program.

- Education: Flipkart has educated its employees and customers about the importance of sustainable packaging. They have also created a number of programs to encourage customers to recycle and reuse packaging.

As a result of their efforts, Flipkart has been able to reduce their plastic usage by over 50%. They are committed to continuing their efforts to make their packaging more sustainable and to help their customers reduce their environmental impact.

	Alternatives	To Replace	Challenges
1	Compostable Bags	Poly based security bags	• Domestic supply not available in quantities required for Flipkart. • Significant cost even at scale. • Not compliant with guidelines across regions.
2	Paper bags with Normal HS Lacquer Coating	Poly based security bags	• Packaging suffered physical damage due to moisture which caused security-related concerns.
3	Paper bags with Fibre Mesh	Poly based security bags	• Manufacturing capabilities could not be scaled to meet requirements and the alternative was cost-intensive.
4	Jute Based Bags	Poly based security bags	• Process not scalable in Fulfilment Centres due to constraints around space and productivity. • Supply of alternatives was not scalable to meet Flipkart's manufacturing requirements and quality standards.
5	Honeycomb Paper Bubbles	Bubble wraps	• Customisation as per application was not possible. Not available in quantities required for Flipkart.
6	Paper Fillers	Bubble wraps	• Process was not scalable in Fulfilment Centres due to constraints around space and productivity. • Tried with some more iterations like developing customised machines that can make 2-ply perforated wraps, the alternative to bubble wrap. These machines were installed at vendor locations. Initially, eight vendors (2 in each Zone) installed these machines to supply the converted material to Flipkart. Later, we expanded this to almost all carton vendors.
7	Eco wraps	Stretch films	• Process was not scalable in Fulfilment Centres due to constraints around space and productivity.
8	Paper wraps	Shrink films	• Packaging suffered physical damage due to moisture which caused security-related concerns.

Table 3: The challenges endured by Flipkart to replace the various SUPs.

The Flipkarts experience demonstrates that businesses have a crucial role to play in reducing plastic waste and creating a circular plastic ecosystem. Flipkart's initiatives towards this goal can be replicated by other players in the same space. It can be learnt that there is a need for systemic change and collaboration across the value chain to achieve this goal.

- Enterprises, particularly those operating within the plastics industry, hold significant responsibility in the efforts to minimize plastic waste and establish a circular plastic ecosystem.
- Other companies within the same industry can adopt and implement similar measures to Flipkart's initiatives in reducing plastic waste, thereby making their own contributions to the reduction of plastic waste.
- Businesses should strategically organize their approaches to include specific goals for reducing plastic usage and effectively managing it throughout their value chain. They should also explore innovative packaging and distribution models to enhance recycling and recovery rates.
- Tailored interventions are necessary to shape consumer behavior and foster collaborations aimed at enhancing and innovating the current infrastructure for waste collection and recovery. These efforts should be aimed at expanding and strengthening the existing systems.
- Leading companies should establish objectives for other organizations that seek to join them in creating an improved response to plastic waste, thereby making a valuable contribution to plastic waste reduction and the overall welfare of society.
- To accomplish the objective, a comprehensive transformation is needed throughout the plastic waste ecosystem, emphasizing the importance of collaboration and innovation across supply chains

Saukhyam Reusable Pads

Plastics are commonly used in various components of sanitary napkins in India. The top sheet, usually made of polypropylene (PP) or polyethylene (PE), provides a soft and comfortable feel. The absorbent core contains superabsorbent polymers (SAPs), which can include plastic materials, to enhance absorbency. The back sheet, typically made of polyethylene (PE), acts as a waterproof barrier. Adhesives used in sanitary napkins often contain plastic components, such as acrylic or polyolefin-based adhesives, to secure the napkin in place. While plastics offer functional benefits, there is a growing demand for more sustainable alternatives

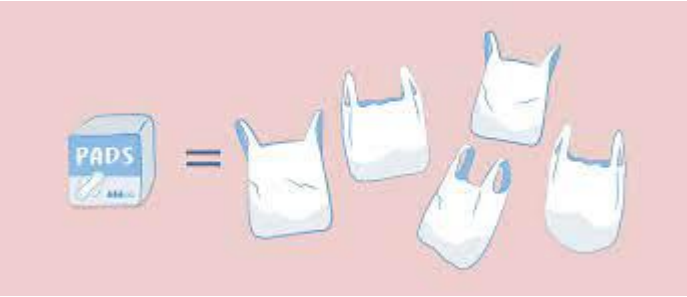


Figure 15: Illustration of the plastic equivalent of a sanitary napkin.

Saukhyam Reusable Pads originated as a research project conducted by Amrita Vishwa Vidyapeetham. In 2013, Chancellor Mata Amritanandamayi announced the adoption of 101 villages across the country as part of the Amrita SeRVe (Self Reliant Village) project, which included various interventions in areas such as health and hygiene.

Upon discovering that only 48.2% of girls and women aged 15-24 in rural areas used hygienic methods of protection during their menstrual periods, as revealed by the National Family Health Survey – 4 (NFHS-4) conducted by the Ministry of Health and Family Welfare, Government of India, efforts were initiated to address this issue with a cost-effective and environmentally friendly solution. This led to the introduction of reusable pads made from cotton cloth and banana fiber, designed to last for 4-5 years. In recognition of their innovation, these pads were awarded the Most Innovative Product Award by the National Institute of Rural Development in India in December 2016.

Figure 16: Banana Fiber in the process of eco-friendly sanitary napkin making.

Saukhyam Reusable Pads can be attributed to several key factors:

1. Environmental Impact: By promoting reusable cloth pads, Saukhyam contributes to reducing the immense amount of single-use plastic waste generated by disposable menstrual products. Each pad has a lifespan of several years, eliminating the need for hundreds of disposable pads per person.
2. Health and Comfort: Saukhyam pads are made from soft, breathable fabrics that are gentle on the skin. Unlike disposable pads that often contain chemicals and synthetic materials, Saukhyam pads offer a healthier and more comfortable experience for women.
3. Empowerment and Education: Saukhyam actively educates women about menstrual health and hygiene, empowering them to make informed choices. They conduct workshops and awareness campaigns to break the taboos surrounding menstruation and promote sustainable alternatives.
4. Social Impact: Saukhyam has created employment opportunities for local women by training them in pad production. This not only generates income for these women but also empowers them by providing skill development and financial independence.
5. Market Acceptance: Saukhyam Reusable Pads have gained significant market acceptance, both domestically and internationally. Their success can be attributed to their high-quality products, ethical manufacturing practices, and commitment to sustainability.

Figure 17: Image of Saukhyam reusable sanitary pads.

The success of Saukhyam Reusable Pads demonstrates the growing demand for sustainable alternatives to single-use plastic menstrual products. By offering an eco-friendly, healthier, and cost-effective option, Saukhyam has inspired individuals and communities to embrace reusable cloth pads as a step towards reducing plastic waste and promoting menstrual well-being.

4. Conclusion

The white paper on alternatives to Single-Use Plastics draws attention to the current research activities, which primarily focus on exploring the characteristics of alternative materials, waste management strategies pertaining to single-use plastics, and the development of alternative products. However, there is a vast potential for further investigation in the realm of SUP alternatives, signaling the need for continued research efforts.

The white paper provides a comprehensive compilation of leading researchers in the field and outlines their respective findings. By presenting this summary, the paper aims to facilitate and encourage future research endeavors, fostering an environment of knowledge sharing and collaboration.

While the market for SUP alternatives boasts a limited number of players, it grapples with imbalances between supply and demand. The existing supply chain exhibits weaknesses, resulting in inadequate distribution to end customers. Despite these challenges, a select group

of companies has managed to establish themselves in the market through the cultivation of unique competitive advantages, carving out a niche for their products.

Notably, the successes of industry giants like Flipkart serve as examples of how major players can consciously transition toward sustainable alternatives. It demonstrates the transformative power of conscious decision-making within influential corporations, inspiring positive change in the market. Additionally, the white paper highlights the case of Saukyam Pads, which illustrates how educating consumers can effectively drive behavioral shifts toward embracing sustainable alternatives.

In conclusion, the white paper underscores the significance of ongoing research in the areas of alternative materials, waste management, and product development for SUP alternatives. By showcasing the achievements of key researchers and outlining the prevailing market challenges, it advocates for continued exploration, while emphasizing the potential impact of informed consumer education and the influence of industry leaders in shaping a sustainable future.

References

1. https://www.statista.com/statistics/1154434/india-net-plastic-consumption/
2. https://www.statista.com/statistics/1344395/india-plastic-consumption-per-capita/
3. https://www.thehindubusinessline.com/news/science/india-generates-946-mn-tonnes-of-plastic-waste-annually/article29299108.ece
4. https://economictimes.indiatimes.com/small-biz/sme-sector/modis-plastic-straw-ban-leaves-indian-consumers-thirsty/articleshow/92995531.cms?from=mdr
5. https://emf.thirdlight.com/file/24/_A-BkCs_skP18I_Am1g_JWxFrX/The%20New%20Plastics%20Economy%3A%20Rethinking%20the%20future%20of%20plastics.pdf
6. https://wwf.org.au/blogs/the-lifecycle-of-plastics/
7. https://planet.outlookindia.com/news/100-mmt-of-single-use-plastic-need-to-be-dealt-with-annually-by-2040-unep--news-415294
8. https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1837518
9. https://planet.outlookindia.com/news/high-concentration-of-plastics-and-microplastics-in-ganga-study-news-414114
10. https://ourworldindata.org/plastic-pollution
11. https://www.sciencedirect.com/science/article/pii/S2772416622000559
12. https://www.bizzbuzz.news/bizz-talk/this-coimbatore-based-startup-is-developing-an-eco-friendly-alternative-to-single-use-plastic-1174857?infinitescroll=1
13. http://rewatergy.eu/microplastics/blog-2

14. Krishnamurthy, Akshaya, and Pavithra Amritkumar. "Synthesis and characterization of eco-friendly bioplastic from low-cost plant resources." *SN Applied Sciences* 1.11 (2019): 1432.
15. Vanapalli, Kumar Raja, et al. "Inhibitory and synergistic effects on thermal behaviour and char characteristics during the co-pyrolysis of biomass and single-use plastics." *Energy* 235 (2021): 121369.
16. Vijayan, Sreelakshmi P., S. Aparna, and Sushanta K. Sahoo. "Effect of beeswax on hydrophobicity, moisture resistance and transparency of UV curable linseed oil based coating for compostable paper packaging." *Industrial Crops and Products* 197 (2023): 116645.
17. Dugvekar, Mitali, and Savita Dixit. "Thermal, structural, and morphological examination of mercerized coir fiber–reinforced composites." *Proceedings of the Institution of Mechanical Engineers, Part E: Journal of Process Mechanical Engineering* 237.3 (2023): 982-988.
18. Gupta, Himanshu, et al. "Preparation and characterization of bio-composite films obtained from coconut coir and groundnut shell for food packaging." *Journal of Material Cycles and Waste Management* 24.2 (2022): 569-581.
19. Vijayalaksmi, M., et al. "Synthesis and Characterization of Banana Peel Starch-based Bioplastic for Intravenous Tubes Preparation." *Materials Today Communications* 33 (2022): 104464.
20. Mahansaria, Riddhi, et al. "Production enhancement of poly (3-hydroxybutyrate-co-3-hydroxyvalerate) in Halogeometricum borinquense, characterization of the bioplastic and desalination of the bioreactor effluent." *Process biochemistry* 94 (2020): 243-257.
21. Nida, Sundus, J. A. Moses, and C. Anandharamakrishnan. "3D printed food package casings from sugarcane bagasse: a waste valorization study." *Biomass Conversion and Biorefinery* (2021): 1-11.
22. Parvathy, P. A., and Sushanta K. Sahoo. "Hydrophobic, moisture resistant and biorenewable paper coating derived from castor oil based epoxy methyl ricinoleate with repulpable potential." *Progress in Organic Coatings* 158 (2021): 106347.
23. Preethi, R., J. A. Moses, and C. Anandharamakrishnan. "Development of anacardic acid incorporated biopolymeric film for active packaging applications." *Food Packaging and Shelf Life* 28 (2021): 100656.
24. Shanmathy, Mrithula, Monalisha Mohanta, and A. Thirugnanam. "Development of biodegradable bioplastic films from Taro starch reinforced with bentonite." *Carbohydrate Polymer Technologies and Applications* 2 (2021): 100173.
25. Sonawane, Prachi, et al. "Potato Starch Based Bioplastic As Alternative Packaging Materials." *African Journal of Biological Sciences* 3.3 (2021): 111-113.
26. Vanapalli, Kumar Raja, et al. "Optimized production of single-use plastic-Eucalyptus wood char composite for application in soil." *Journal of Cleaner Production* 278 (2021): 123968.
27. https://www.tgpbio.com/_files/ugd/7eae64_be5f3b4aef3e464fad1f47b1fb5d47e0.pdf