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Green Plastic: An Innovative Concept for Pollution Control

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Abstract

Plastics are referred "green" if they exhibit one or more of the following properties: source renewability, biodegradability/compost ability after end of the life and environmentally friendly processing. Vast majority of the plastics today are originated from petroleum based hydrocarbons and therefore made from non renewable resources. Even though less than 5% of the petroleum is used in plastics manufacturing, the renewability of the source is often a concern. The linear economy for plastic packaging, which currently leads to excessive carbon dioxide emissions and leakage into the environment, needs to be reformed to a greener circular model which is resource efficient and environmentally benign. This requires a system-wide redesigning of rules and incentives that apply to the plastics value chain, from product design to recycling and end-of-life options. To understand this field of green chemistry, sometimes referred to as sustainable chemistry, seeks to create chemical products and processes that minimize or do away with dangerous materials while advancing sustainability. Its main goals are to reduce waste, increase energy efficiency, and employ renewable feedstocks in order to improve the environment and the economy.This paper is an investigation into facts about green plastics, its current status, advantages, shortcomings and other related issues. The conclusion reached would comment on the future of green plastics and its scope as a replacement for petroleum based plastics.

Key words*: advancing sustainability, renewable feedstocks, dangerous materials etc.*

Introduction

Green chemistry is the design of chemical products and processes that reduces or eliminates the use or effects of hazardous substances. Green chemistry applies across the life cycle of a chemical product, including its design, manufacture, use, and ultimate disposal.

Green chemistry is a science based philosophy of designing chemicals and processes with the intention of making them less hazardous and more sustainable. It applies to the life cycle of a chemical, from creation to disposal.

When applying the principles of green chemistry during the design phase it helps in prevent pollution at the source by making safer chemicals and it reduces or eliminates the use of toxic chemicals which protects workers, consumers, and the environment. And it also reduces energy and material use while increasing the use of renewable materials.

Green chemistry is a part of sustainable design which is a way for scientists and engineers to provide innovative and creative ways to reduce waste, conserve energy, and replace hazardous chemicals with safer alternatives. These tools can help you to incorporate sustainability practices. Green chemistry has been used in a wide variety of products and processes, from the medical field to computer technology to household paint.[1]

Plastic is the need of time due to its applications and low manufacturing cost but the hazards produced by it are provoking scientist, particularly green chemist to develop better and non-hazardous replacement for it. The present work describes the development of a novel method of preparation of biocomposite and green plastic from caltrops procure and its physiochemical characterization. Simultaneous measurement of effective thermal conductivity and effective thermal dissusitivity of fibers of caltrops procure reinforced urea formaldehyde composite have been studied by transient plane source techniques. Effect of different parameters viz pH, medium, concentration and time have been investigated for the isolation of fiber. A dip is integrated as the glass transition region. The activation energy is very important parameter that gives information about the nucleation and growth process in the solids. The experimentally obtained data are analyzed on the basis of Kissinger equation in order to determine activation energy. The crystallization process under non-isothermal conditions has always been analyzed in terms of onset crystallization temperature Tc and activation energy. it has been found that, the activation energy in glass transition region of the composite decreases with increase in the fiber fraction in the crystallization region shows weak dependence on the heating rate while depends fully upon fiber traction in the composite. Further use of micelle medium not only increases the rate of decomposition but also provides better quality fiber from caltrops procure and controlled medium provides fine quality powder, which can be converted into green plastic.[2]

Green Plastics Classification

Based on the definition of green plastics in the previous section, E. S. Stevens classifies modern day green plastics into three categories. (i) Polymers extracted directly from biomasses (plants or animals), with or without modification (Referred Type I here after). For example polysaccharide starch modified polymers and polymers derived from cellulose. (ii) Polymers processed directly by microorganisms through large scale fermentation process (Referred Type II here after). For example polyhydroxyalcanoates (PHA), copolymer of Polyhyrodxy butyrate and hydroxyvalerate (PHBV). (iii) Polymers obtained from resins (monomers) produced with renewable and naturally occurring raw materials (Referred Type III here after). For example polyesters such as polylactic acid (PLA) processed from naturally occurring lactic acid monomer.

Table 1: Green Plastics Materials and Properties

Type	Origin	Examples P	Products	Utility	Disadvantages	Advantages
Type I	Polymer extracted directly from biomass	Poly-saccharides (Starch)	Non Durable Goods: packaging, thin film bags	Medium	Modest strength, poor water resistance	Low cost
Type II	Polymer from large scale fermentation of biomass	PHBV	Durable Goods: Coating type I plastics for water resistance, blow molded containers, toiletry articles, office accessories	Low	High cost of synthesizing the polymer, Narrow melting range	Superior physical properties, good water resistance
Type III	Monomer extracted from biomass	PLA	Non Durable goods: Disposable Plates, cups, boxes, film wraps	High	Low thermal resistance, brittleness, high specific weight	More cost effective than Type II, optical clarity, good moisture resistance

Recycling Issues Plastics

Recycling fall into two categories: pre-consumer and post-consumer. Pre consumer one involves recycling of waste generated while manufacturing the product such as trim wastes after thermoforming or runner and spree waste from post injection molding. Most manufacturers are focused on recycling the pre-consumer waste at the source itself. The problem arises with post consumer recycling of bioplastics after its end use. Recycling post consumer waste is a tedious and expensive process as it involves considerable amount of cleaning and sorting activities. Within the petroleum based plastics it is not easy to determine the difference between similar plastics such as PE or PP. One of the major hurdles in recycling is that these different polymers are not mixable. Mixing of bioplastics with petroleum based plastics could contaminate the oil based plastic feed generated from recycling. A mixture could result in inferior properties leading to an unusable recycled plastic for many processes. This is very likely to happen as the consumers may not differentiate between different plastic types. Therefore bioplastics should be from identifiable sources that will allow for sorting. Currently in the United States, very less infrastructure exist to collect bioplastics in sufficient quantities and consumers do not have a clear picture on its recyclability. Another option of dealing with post-consumer plastics is composting. It should be noted that one of the biggest myths about landfills is that they are giant compost pits which not true. In fact anything that goes into a landfill (bioplastics or oil based plastics) will not decompose properly because or the lack of sunlight and air. Therefore composting bioplastics needs additional infrastructure and setting to handle the volume. Commercial bioplastics such as PLA would compost only in municipal and industrial compost settings.[3]

Processing Green Plastics Products

Products made of biodegradable plastics must be stable during processing. Most of the green plastic materials are processes by methods such as thermoforming, injection molding, blow molding and extrusion. These processes demands mechanical and physical properties such as melt strength, flow, elongation, temperature resistance, elasticity. Most of the green plastic materials have property issues such as modest strength, low water and temperature resistances, lower impact strength etc. Therefore these materials requires improvement and modification and hence most commercial bioplastics are composed of several chemicals such as additive stabilizers, colorants etc which makes it almost impossible to be manufactured from 100% renewable resources (most of the bioplastics now contains 50% renewable resources).[4]

Methodology

The data for this study was gathered in a systematic way from credible sources, starting with a collection of relevant keywords for searching and obtaining material from databases and presenting the literature analysis. According to tran field et al. The purpose of a literature review is to discover gaps in the existing literature and knowledge constraints. In short, the study used a four-step technique that included identifying the data, screening preliminary data, evaluating eligibility, and ultimately including the data. The purpose of gathering this information is to propose new ideas and suggestions for future study. The researchers used the Scopus and Web of Science (classifications and insights) databases to compile their findings. Many researchers grad the Scopus database as trustworthy. Furthermore, academicians have praised the Web of Science database for high-quality indexing information. Much previous research has relied on it as a credible and high-quality data source.

Metadata analysis

The data was compiled using the Scopus and Web of Science into grated databases. The search includes all papers published between 1990 and 2022. TITLE-ABS-KEY ("Biodegradable plastics OR green pack aging" OR bioplastics OR bio-based plastics") are the words used in the study. The initial search criteria were limited to the article's title, abstract, and keywords. Six hundred and seventy-five pages were first created using three keywords. In addition to articles, the first search result contained conference papers, books, and book chapters. Except for the articles, all (conference papers, books, and book chapters) were finally withdrawn. Cones queenly, following the first refining, 3484 papers survived as articles. After deleting duplicates, a total of 3462 publications were selected for the metadata analysis. The researchers used 3462 Scopus articles for metadata assessment and 174 Web of Science articles to give insights and future prospects. Papers that appear in the Web of Science web browser are also included in Scopus. The metadata study included publication dates, jour nails, nations, topic areas, and institutions for articles. To improve reading, some of the statistics in this study are presented in a summary style rather than a full list. The researchers used 174 articles to give insights and prospects. As a result, the study reveals that the information is taken from trustworthy sources. Furthermore, because it indexes journals from other important databases such as Science Direct, Wiley, Elsevier, Emerald, MDPI, Taylor & Francis, IGI Global, Springer, and others, these databases are apron pirate for generalizability purposes. On the other hand, the data should originate from a much more reputable source to convey the insights and prospects for the future. Many previous researches used subjective judge meant to choose data to analyses the collected data.[5] As a result; data were rigorously acquired from the Scopus and Web of Science using keywords each to verify that the data originated from a rich data source and kept an impartial conception of the study. Papers that appear in the Web of Science web browser are also included in Scopus.

Results and discussion

The audit included a specification of the facility and the processes. Only the block diagrams of the processes for the production of crushed flakes of PET (Figure 1) and the production of PET film for thermoforming (Figure 2) are shown here, i.e. only for those processes in which the implementation of the principles of green chemistry is proposed. Other plant parts or processes as well as energy flows will not be considered here. Therefore, the presented results are the analysis of chemicals ("chemical inspection"), water and wastewater streams, as well as the analysis of the generated waste.[6]

As part of the "chemical inspection", a review and analysis of the contents of 26 SDSs for substances and mixtures used in the company was carried out. Here is a brief overview of the research, where commercial names of substances are not listed for reasons of confidentiality. Table 1 provides an overview of the most commonly used chemicals with the amounts consumed in 2023. In the production process, the largest quantities of chemicals are used in the washing process, specifically sodium hydroxide and detergents. In smaller quantities, appropriate additives are used in the facility to enhance certain product properties. Aerosols in the form of pressurized sprays are used as needed for corrosion removal, lubrication (containing concentrated silicone oil), and surface cleaning. All the mentioned aerosols do not contain persistent, bioaccumulative, and toxic (PBT) substances, very persistent and very bioaccumulative substances, SVHC, or contain them at less than 0.1% w/w in their composition.[7]

Sodium dichloroisocyanurate dehydrate (Na.DCC) is used as a disinfectant. This substance can be found in the form of white crystals, powder or tablets. Na.DCC is a stable salt that contains chlorine and is soluble in water, forming a solution containing hypochlorous acid and isocyanurate acid. This solution is an effective disinfectant used for water disinfection, including drinking water, swimming pools, public bathrooms, and other facilities where maintaining hygiene is crucial. NaDCC has advantages over other disinfectants like chlorine as it has a milder odor and is less irritating to the skin and mucous membranes.[8] Additionally, Na.DCC can be used in smaller quantities compared to other disinfecting agents, which can reduce its environmental impact. Although NaDCC is considered relatively safe, it is essential to handle it with care as it can be irritating to the eyes and skin and harmful to health in larger quantities. Na.DCC is harmful if swallowed (H302), causes serious eye irritation (H319), may cause respiratory irritation (H335), and is very toxic to aquatic life with long-lasting effects (H410). Therefore, special precautions are necessary when handling it, following the S.D.S.

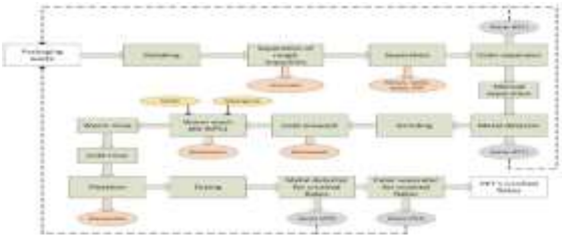

Figure 1. Block diagram of the process for the production of PET´s crushed flakes

To prevent the occurrence of electrostatic electricity in plastic packaging and consumer goods, an effective antistatic agent is used (safe for food contact). It neutralizes the static charge that polymeric materials acquire during production and processing. The antistatic agent can cause severe eye damage (H318) and is toxic to aquatic life (H411). The active ingredient is registered on the positive list for "food grade materials" in accordance with Regulation (EC) No 1935/2004. To reduce adhesion between surfaces, another additive (antilock) is used, which does not contain hazardous substances and is safe for use.[9]

The mixture used as an antifoaming agent and flotation aid is a combination of highly efficient substances (nonionic and anionic surfactants) that suppress foam formation and additives that assist in separating PET and HDPE or PP through the flotation process. This mixture is classified as hazardous because it can cause severe eye irritation (H319) and is harmful to aquatic life with long-lasting effects (H412). However, the mixture contains (<0.25% w/w) octamethylcyclotetrasiloxane (D4) (CAS 556-67-2), which is classified as an SVHC according to ECHA due to its PBT and VPVB properties. For this reason, it has been included in the Candidate List for authorization, which means a complete ban on its use can be expected very soon. The same mixture contains (<1% w/w) decamethylcyclopentasiloxane (CAS 541-02-6), known as D5, which is classified as an SVHC substance due to its PBT and VPVB properties and is included on the Candidate List for authorization.[10]

D4 and D5 are also on the List of substances proposed as POPs, which means that they are being prepared for their potential inclusion in the Stockholm Convention. In the Republic of Ruska, D4 and D5 are on the List of substances that are candidates for inclusion in the list of SVHC by Ministry of Health and Social Welfare.[11]

Figure 2. Block diagram of the process for the production of PET film for thermoforming

Table 1. Data on the type and consumption of chemicals

Chemical name	Location of use	hazard statement	consumption in 2023
Caustic soda	Warm wash process of PET´s crushed flakes (Fig. 1)	Corrosive. Hazards: May be corrosive to metals (H290). Causes severe skin burns and eye damage (H314)	10 - 12 t
Detergent and cleaning agent 1	Warm wash process of PET´s crushed flakes (Fig. 1	May cause eye damage (H318)	1.44 m3
Detergent and cleaning agent 2	Warm wash process of PET´s crushed flakes (Fig. 1)	Irritating to skin (H315). Causes eye damage (H318). Harmful to aquatic life (H412)	2 m3
Antifoam and flotation agent	Flotation (Fig. 1)	Causes severe eye irritation (H319). Harmful to aquatic life (H412). Contains SVHC substances	700 kg
Antistatic	Production of PET foil (Fig. 2)	Causes severe eye damage (H318). Toxic to aquatic life with long-term effects (H411)	0.1 m3
Antiblock	Production of PET foil (Fig. 2)	It is not a dangerous substance	100 kg

The report of the environmental audit was presented to the management of the company Monika Reciklaža Ltd. who accepted the implementation of the proposed measures. Currently, measures 1 and have been implemented, and measure 2 will be implemented later. With the implementation of measure 1, the antifoam and flotation agent was taken out of use without affecting the quality of the product.[12] The company's staff tested the possibility of performing flotation without this agent and the dangerous mixture was completely phased out by December 2022. This reduced the cost of purchasing the given chemical. By installing new bag filters in January 2024, measure 3 was implemented. Filters (diameter 20 cm, length 4 m) are installed on the line for the production of PET´s crushed flakes, after the drying process (Fig. 1), where a large amount of PET dust appears. Bag filters contain antistatic, suitable for working in certain explosive zones. So far, it has been observed that the amount of dust in the production facility is lower compared to the period when the old dust collection system was used. Monitoring of this measure continues.

Conclusions

Green chemistry and the EU REACH regulation, as the main drivers of implementing green chemistry principles in the industry, promote sustainability and the reduction of the harmful impact of chemicals on the environment and human health. Through an environmental audit, the possibility of improving the technological process for this case study in the plastic recycling industry has been identified in terms of applying the principles of green chemistry, with the aim of protecting human health and the environment. The proposed 3 measures result in:

- Ceasing the use of a mixture containing two substances (organosiloxanes) classified as SVHC and substances proposed as POPs.
- Reducing the amount of waste PET dust while simultaneously increasing the production of PET dust for the market (byproduct).
- Reducing the consumption of chemicals in the warm washing process by water demineralization treatment while increasing the efficiency of the heater and increasing energy consumption.

Bioplastics Future Perspectives

Bioplastics are continually evolving. Researchers are actively working on developing the next generation of bioplastics. Ongoing research focuses on developing factors s Kuruppalil, Z. (2010, November). Plastics packaging: The challenge of going green. Accepted to publish in The First International Conference on Green and Sustainable Technology conference proceedings, University of North Carolina a&t. much as recycling methods, cost, durability, and biodegradation. The Circe project is one innovation in bioplastic that uses engineered microbes to produce biodegradable plastics. Unlike traditional bioplastics made from crops, Circe's microbes feed on carbon dioxide and hydrogen gases to create eco-friendly polymers suitable for various products, from packaging materials to cosmetics. Shrilk is another innovation that derives its base materials from shrimp shells (chitosan) and silk protein (fibroin). These innovations represent promising steps toward more sustainable bioplastics. Future bioplastics will resemble traditional plastics but with reduced environmental impact. In the future, the industry plans to transition from edible first-generation biomass to non-food crops. More efficient methods for using second-generation biowastes must be developed. While advancements are underway, individuals can also contribute by reducing disposable plastic use.[13]

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