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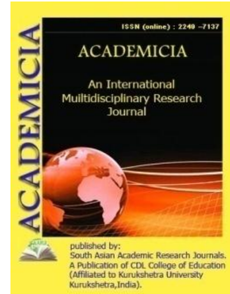

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PLASTIC SOLID WASTE RECYCLING: A STATE-OF-THE-ART ASSESSMENT AND POTENTIAL APPLICATIONS

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ABSTRACT

Plastic solid waste (PSW) of polymers such as high density polyethylene (HDPE), low density polyethylene (LDPE), Nylon, and others) is posing new difficulties, which are significant research concerns in today's situation. Production of various goods made of various plastic materials has increased dramatically. This massive rise in plastic goods has resulted in increased trash production, posing new problems. Some studies have published findings in the area of PSW management using various recycling techniques. This article summarizes the numerous research projects undertaken by researchers in the area of recycling, as well as the progress made in the recovery and management of PSW using various methodologies (i.e. primary, secondary, tertiary, and quaternary) and various identification/separation approaches. This study also looks at how various reinforcements, such as sand, natural fiber, hemp fiber, metal powder, and others, affect the characteristics of virgin and recycled HDPE/LDPE/Nylon PSW.

KEYWORDS: *Plastic Waste, Plastic Trash, Polymers, Recycling, Solid Waste.*

INTRODUCTION

Plastic solid waste (PSW) recycling, recovery, and management is a problem in today's world. Many commodities are produced using plastics, and industries are becoming increasingly interested in the area of plastic production. Plastics have become an integral element of modern life, and worldwide plastic manufacturing has skyrocketed in the previous 50 years. Traditional plastics are very durable and do not breakdown easily in the environment[1]. Plastics will never disintegrate and will stay on the landscape for many years. In typical environmental circumstances, polymer takes hundreds of years to decompose. Plastic trash is hazardous because its pigment includes many extremely poisonous trace elements. As a consequence, environmental contaminants emitted by synthetic plastics have been recognized as a major source of concern. PSW is manufactured on a large scale throughout the globe, with annual output exceeding 150 million tonnes. Every year, India consumes about 8 million tonnes of plastic goods, with this figure projected to increase to 12 million tonnes by 2012.

Plasticized PVC is widely used in the manufacture of pipes, window frames, floor coverings, roofing sheets, and cables, and as a result, it is often discarded. Packaging films, wrapping materials, shopping and trash bags, fluid containers, clothes, toys, home and industrial goods, and construction materials are among its many uses. Furthermore, a virgin plastic material can only be recycled 2 to 3 times since the strength of the plastic material decreases with each recycling owing to heat deterioration[2]. Solvents with hydrogen donor capabilities, in particular, have a role in the thermal breakdown of polymers, influencing hydrocarbon production and dispersion. It is worth noting that no accurate estimate of total plastic trash production exists; nevertheless, given that 70% of total plastic consumption is thrown as garbage, the nation generates about 5.6 million tons of plastic waste per year (TPA), or about 15342 tons per day (TPD) (CPCB). A study was performed to examine the demand for different kinds of plastic. PVC, PP, and HDPE all contribute more to the use of plastic, as can be seen in this bar graph. Plastic use is rapidly rising due to a variety of benefits like as flexibility, cheap cost, and excellent chemical stability[3]. Plastic trash from household waste is mostly made up of polyethylene and polypropylene. The more the consumption, the greater the demand for recycling to reduce the usage of raw materials. HDPE (high density polyethylene) LDPE (low density polyethylene) and nylon are the most common raw materials for plastic goods. Plastic makes up a large portion of municipal solid trash, and it is often made up of packaging debris as well as abandoned equipment and products. It cannot be dumped into the environment because of its nature. As new goods are launched on a regular basis, this figure is worsening. This may be very harmful to the ecology and the planet. Plastic trash is causing issues for the environment as well[4].

According to a research, greenhouse gases such as methane emissions produced by fossil fuels have the potential to cause global warming. The trash that is generated on a daily basis, on the other hand, has a far greater potential to release carbon dioxide as a greenhouse gas. It's worth noting that carbon dioxide has 21 times the global warming potential of methane. Plastic polymer use and manufacturing are determined by demand and availability. However, the use and manufacturing of different plastic polymers are not equal in India. In India, each individual consumes 9.7 kilogram of plastic[5]. The study produced by Tata Strategic on the use and production of different plastic wastes. This data plainly shows that there is a significant disparity between polymer demand and production. The use of fresh material to fill these voids is on the rise. Plastic product use can only be decreased to a limited degree, but new material usage may be minimized via recycling and management methods. Many studies on PSW recycling and recovery have been published[6]. In a study, the Delhi-based Central Pollution Control Board claimed that 90% of PSW is recyclable. Eighty percent of post-consumer plastic is disposed of in landfills, eight percent is burned, and seven percent is recycled. Because land filling of HDPE has severe implications in terms of GHG (greenhouse gas) generation, PSW may be made acceptable for other uses by using various techniques.

Aside from the environmental problems associated with land filling, disposing of vast quantities of leftover fabric is a significant waste of resources and energy. The application domain of recycled plastic may be expanded by strengthening various particles. It may be used to create particle board because wood-based particle boards are formed by compressing different layers with urea formaldehyde-containing glue or resin, and this formaldehyde has the potential to cause a variety of illnesses, including cancer. HDPE, polypropylene (PP), polyvinyl chloride (PVC), wood flour, modified MMT, and glyceryl methacrylate are blended to make a wood plastic composite (GMA). As a result, recycled plastic may be utilized as a resin. Primary, secondary, tertiary, and quaternary recycling methods may all be used to recycle materials[7]. All kinds of polymers and metals may now be recycled thanks to technical advances in industry. Three techniques of plastic recycling have been proposed by certain researchers. The first step is to mechanically separate plastic trash for secondary usage. The second approach is divided into two parts: energy recovery via incineration and pyrolysis for use as fuels or polymer feedstock. The third technique involves bringing the polymer to the point of biodegradation, although this is extremely dependent on the kind and environmental circumstances. Following this, it can be stated that plastics play a significant role in municipal and industrial trash. This article focuses on the processing of various plastic-based products as well as their recycling techniques.

PSW is a significant contributor to the trash produced on a worldwide scale. Because of the increasing production and use of polymer materials, polymer disposal is becoming a worldwide problem[8]. The varying levels of waste production in many nations depending on their socioeconomic levels has become a significant problem for PSW disposal and management. Trash management is a complicated process that requires a variety of data from many sources, such as influencing variables in waste production, large-scale predictions, and trustworthy data. Each year, at least 93 million tonnes of trash are produced throughout Eastern and Central Asia[9]. The amount of trash generated per person per day varies from 0.29 to 2.1 kilograms, with an average of 1.1 kg/capita/day (OECD report 2010). The Organization for Economic Co-operation and Development (OECD) is a 34-country international economic organization that includes AFR (Africa), SAR (South Asia), MENA (Middle East and North Africa), ECA (Eastern and Central Asia), LAC (Latin America and the Caribbean), and EAP (East Asia and the Pacific Region). Solid waste management accounts for less than 5% of worldwide greenhouse gas emissions (GHG). International effort to reduce greenhouse gas (GHG) emissions is increasing in response to rising worries about the danger of climate change, and the solid waste management industry is anticipated to play a role[10].

DISCUSSION ON RECYCLING OF PLASTIC WASTE

PSW recycling is restricted to a certain number of cycles since the product loses some of its characteristics after recycling, such as strength and stability. After a certain amount of recycling, the only option for disposing of PSW is to land fill it. However, land filling pollutes the earth's surface. Land filling also results in carbon dioxide emissions. Plastic also leads to health problems such as skin corrosion/irritation, aspiration danger, severe eye damage/irritation, and so on. Because polymerization processes take a long time to complete, unreacted residual monomers are often discovered in polymeric materials, many of which are harmful to human health and the environment. As a result of the many polymers/plastic-based products available on the market or as trash, Thermosetting long strands and thermoplastic short link materials are the two main types of plastic. Thermosetting plastic materials cannot be recycled again, while thermoplastic plastic materials may be recycled to some extent. The emphasis of this review is only on thermoplastic materials.

Low Density Polyethylene (LDPE), High Density Polyethylene (HDPE), Polypropylenes (PP), Polystyrene (PS), Polyethylene Terephthalate (PET), and Polyvinyl chloride are the six major families of plastics (PVC). Virgin plastics are readily accessible and produced using traditional methods, yet they are on the brink of replacing fossil fuels in terms of energy use. To begin with, plastics may be thought of as a kind of stored potential energy since the manufacturing of virgin plastics consumes 4% of global oil output, or 1.3 billion barrels per year. As a result, it is always a good idea to reuse and recycle plastic trash. This effort discusses and elaborates on some of the most well-known and widely utilized plastics. PVC is a versatile polymer that may be made into a broad range of short- and long-term goods. PVC usage accounts for 12 percent of overall demand among these main kinds of plastics. In 2013, the global PVC manufacturing capacity was estimated to be about 61 million tons. Plastic recycling is mostly determined by the kind of plastic. The kind of plastic is not guaranteed by trash collection. The problem of recycling compatibility must be addressed first. There may be a lot of plastics in a collection. To separate out different materials, segregation of plastic is required. Because of the various melting temperatures, combining one polymer with another may result in a decrease in the characteristics of recycled material. LIBS (laser induced breakdown spectroscopy) is a novel analytical method that uses pulsed laser sources. It's used to distinguish between different types of plastic trash. The study of the main constituent carbon and hydrogen contained in polymer matrices demonstrates the capabilities of this method.

For spectrum analysis and fingerprinting of different types of plastics, a laser-produced plasma emission is recorded. This method can identify a total of six plastic materials: Low Density Polyethylene (LDPE), High Density Polyethylene (HDPE), Polypropylenes (PP), Polystyrene (PS), Polyethylene Terephthalate (PET), and Polyvinyl chloride (PVC). Calibration is accomplished by shining a laser beam of a particular wavelength from a laser onto some previously recognized plastic waste material. For all PSW materials that need to be recognized, this process is followed. The key to successful recycling is accurate and efficient plastic identification and categorization. Because the value of recycled materials is determined by fraction purity, it is possible to make more precise decisions regarding separation technology based on the identification of the plastics. - Electrostatic separation is a phrase used to describe a large class of contemporary waste management technology that is widely used for separating granular mixes using electrostatic forces acting on particles with a typical size of about 5 mm. This is also known as free-fall. Triboelectric separation is extensively used for sorting and purifying granular materials derived from industrial plastic waste. In addition, there are two different kinds of triboelectric separation methods. One is a roll-type corona-electrostatic separator, which is used to separate plastic materials from metal components. When two materials are fed and spun at a certain speed in this triboelectric separator, the material within experiences two kinds of forces: particle/particle forces and particle/cylinder wall forces. When two materials rub against one other, charge appears on the particles of the materials. One receives a positive charge, while the other receives a negative charge. Then When a material particle travels through a strong electrostatic field, forces operating between them cause separation.

When PVC is brushed with Teflon, for example, the latter gains a negative charge while the PVC gains a positive charge. Almost any plastic substance may be sorted out using this kind of separation method. However, the greatest separation of material with a particle size of 2-4 mm is limited by this method. Furthermore, it is a method for determining the chemical composition of a broad variety of materials, including metals, cements, oil, polymers, plastics, and the food sector. If excellent reference specimens are available, this method should provide very high accuracy. The time it takes to measure particles varies depending on the amount of components to be identified, and it may take anywhere from a second to 30 minutes. This method involves irradiating a sample with x-rays generated by a source. In most instances, x-ray tubes are utilized, although synchrotron or radioactive material may also be used. The under-inspection element will emit fluorescent X-ray radiation with distinct energies (corresponding to colors in optical light) that are unique to specific elements. A distinct color represents a different amount of energy. It is possible to identify the element by measuring the colors emitted by it. This is a qualitative study. The intensity of color may also be used to determine the quantity of an ingredient. By comparing the spectra of waste samples to those of various model polymers, FT-IR is utilized to identify different kinds of polymers and plastic materials. It's used to get an infrared spectrum of a solid, liquid, or gas's emission or absorption.

A FTIR spectrometer gathers high spectral resolution data across a broad spectral range at the same time. This gives it a big advantage over a dispersive spectrometer, which only measures intensity across a small range of wavelengths at a time. The structural changes as a function of strain are also investigated using FTIR spectroscopy. FTIR spectroscopy has previously been utilized to investigate structural changes as a function of strain. This technique is currently being utilized to analyze the structural changes that occur during polymer recycling. This method was used to separate PET, PVS, and PS, with extremely remarkable results in plastic separation, with 83 percent of the PET being recovered. Another polymer separation method used to detect various plastic polymers is froth flotation. Alter was the first to suggest that froth flotation might be used to recover plastics based on their critical surface tension. Some writers have discovered an issue with huge amounts of plastic garbage. Because of the hydrophobic characteristic of all plastic/polymer materials, froth flotation is difficult because air bubbles in the substance cause it to float. Flotation of material is caused by both hydrophobicity and gravitational force linked to mass. For the recovery of polymers in this experiment, wetting and foaming agents are required. As a wetting agent, calcium lignin sulfate is employed, as well as pine oil and MIBC (methyl isobutyl carbinol) as a foaming agent. When pine oil is employed as a foaming agent, PVC recovery improves, while MIBC findings favor PET recovery.

Overall, froth flotation has been identified as a significant and efficient separation technique in mineral processing engineering, as well as a helpful approach for separating mixed polymers. The material to be separated is first fed into the first tank, then mixed with hot water with the aid of an electro- magnetic feeder. The average residence duration in this tank will be determined by the time it takes for appropriate mixing and full particle contact with water prior to caustic/alkaline treatment. Another container is used for the alkaline treatment. Again, the mean residence time must be chosen for mixing. After that, the pulp will be formed and passed through a vibrating screen to be rinsed with cold water. The surfactants are present in a tank where the wetted material and cold water are supplied for chemical treatment. The length of time spent in residence is determined by the kind of alkali and chemical employed in the conditioning process. The alkali liquid's pH should be kept steady. The temperature of the water used for alkali treatment is critical and has a significant impact. Because it is often impossible to achieve high temperatures owing to a lack of adequate water heating equipment. After that, samples from various product streams may be isolated and collected at predetermined time intervals for examination and product weight estimation. The plants used for this treatment take up a lot of room, and cleaning and washing the materials has become a time-consuming task. Even if it necessitates more room for the plant installation, washing plants should be built in such a manner that every component can be readily accessed and cleaned. A separation technique that can detect very tiny changes in physical characteristics is required to generate high purity material from complicated streams of post-consumer trash of grade similar to materials produced by post industrial waste. This technique may aid in the separation of usable plastic from trash with the least amount of residual material.

After manual sorting, this technique focuses on identifying main plastic included in a certain waste composition. MDS is a physical separation technique based on material density differences. This optical sensing method may be used, however due to the size of the plastic substance present, it is not always effective. Separation by density is another technique. Electronic trash may be separated using this method by adding a modifier to water, although it may contaminate recovered plastic. It's used to separate polypropylene (PP), low density polyethylene (LDPE), and high density polyethylene (HDPE) from one other, as well as contaminated materials including wood, rubber, and minor metals. Because MDS separates a complicated mixture into several distinct components in a single stage using the same liquid, it has the potential to be extremely inexpensive. The whole procedure is carried out while the mixture runs through a conduit, and the layers are separated in seconds. There are four stages to setting up MDS: I Wetting, (ii) Feeding, (iii) Separating, and (iv) Collecting are the four steps in the process. The MDS setup's components are immersed in the liquid surface. The liquid utilized in this procedure is magnetic in nature and circulates throughout the setup, moving from left to right under the effect of pressure differences before returning. To make the surface hydrophilic and remove heavy polymers, the materials are first wetted with hot water for a minute.

Wet particles are placed in a stainless steel box with 1mm holes. To prevent turbulence produced by air in the system, the air in the feeding box is first evacuated before the box is placed in position. When the box's lid is opened, the particles begin to rise and subsequently flow into the separation channel with the mainline; here, the density of the material plays an important role. Different kinds of materials are available in powder and granule form on the market. The material is fed into the barrel by gravity via the hopper. The heaters that surround the cylindrical barrel may be regulated manually using a variety of temperature ranges. The temperature range of a standard screw extruder is typically up to 275 degrees Celsius, which is sufficient to melt thermoplastic materials. As soon as the material enters the barrel, it begins to heat up. The material begins to move forward, towards the die, as the screw turns. The length of the barrel is crucial. Screw speed has a significant influence as well. The material will not melt correctly if the screw has a higher speed because the substance will lead at a quicker pace. If the screw speed is too slow, the material will be overheated and the wire will not properly form. The screw forces the material positively into the barrel and leads it to the die. Melting temperature is a key characteristic that influences the flow properties of polymers. Multiple heating zones are possible. These heating zones progressively raise the material's temperature. The pressure exerted by the screw on the material may exceed 5000 psi (34 MPa). After then, the material reaches the breaker plate, causing back pressure. This is necessary for consistent material melting and mixing.

CONCLUSION AND IMPLICATION

This article discusses the many problems of PSW management, including material recycling. Reducing the usage of virgin materials and repurposing PSW will help to ensure the environment's and global warming's long-term viability. Landfilling, being the most convenient method of disposing of PSW, is growing worldwide problems while also raising space requirements. This article discusses different technologies, as well as separation methods, reinforced plastic material, and uses of reinforced PSW, in order to minimize land filling. The different separation/identification methods for PSW, such as froth flotation and MDS, are discussed in this article. Froth flotation is the most often used technique for separating large quantities of PSW in a single term. Contamination of collected trash due to lack of plastic separation may decrease the characteristics of the bi-product. Primary and secondary recycling techniques are widely utilized in Asian nations, however they have drawbacks in terms of losing different characteristics of PSW acquired as a by-product and using a lot of energy. Various researchers have attempted to produce goods with comparable characteristics to virgin material using a variety of different methods, such as tertiary, which involves chemical treatment of PSW in order to recover energy from the polymer, which is a petroleum product in the form of heat. Further, incineration is a recycling method in which PSW is utilized as fuel since it is a petroleum bi-product with little calorific value, resulting in natural resource sustainability. By reinforcing different fillers in polymer material to improve the characteristics, recycling of products using filler material is also becoming an interesting area.

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