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Recycling of plastic solid waste: A state of art review and future applications

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ABSTRACT

Plastic solid waste (PSW) of polymers (like: high density polyethylene (HDPE), low density polyethylene (LDPE), Nylon etc.) is creating new challenges, which in today's scenario are major research concerns. A sharp rise has been observed in production of different products based on different plastic material. This huge increase in plastic commodities also increases the waste generation thus creating new challenges. Some researchers have reported work in the field of PSW management with different recycling methods. This paper compiles the different research work done by researchers in this field of recycling and progress in recovery and management of PSW by different methods (i.e. Primary, secondary, tertiary and quaternary) along with the various identification/separation techniques. Further, this paper reviews the effect on properties of virgin and recycled HDPE/LDPE/Nylon PSW with different reinforcements like sand, natural fibre, hemp fibre, metal powder etc.

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1. Introduction

In today's scenario recycling/recovery/management of the plastic solid waste (PSW) is a matter of concern. Industries are getting more interested in the field of plastic manufacturing; so many commodities are being manufactured with plastics. Plastics have become a crucial part of lifestyle, and the global plastic production has increased immensely during the past 50 years [54]. Traditional plastics are very strong and not readily degraded in the ambient surroundings. It is a fact that plastics will never degrade and remains on landscape for several years. Polymer needs hundreds of years to degrade in normal environmental conditions [98]. Plastic waste is harmful as its pigment contains many trace elements that are highly toxic [51]. As a result, environmental pollutants from synthetic plastics have been identified as a huge hassle [149]. PSW is being produced on a massive scale worldwide and its production crosses the 150 million tonnes per year globally. In India approximately 8 Million tonnes plastic products are consumed every year (2008) which is expected to rise 12 million tonnes by 2012. Plasticized PVC has a common use manufacturing of pipes, window framing, floor coverings, roofing sheets, and cables; thereby it is discarded at a high rate [63]. Its broad range of application is in packaging films, wrapping materials, shopping and garbage bags, fluid containers, clothing, toys, household and industrial products, and building materials. Further, the recycling of a virgin plastic material can be done 2 to 3 times only, because, after every recycling, the strength of plastic material is reduced due to thermal degradation. Particularly, solvents with a hydrogen donor capability take part in the thermal degradation of polymers affecting the hydrocarbon yield and distribution [137]. It is to mention that no authentic estimation is available on the total generation of plastic waste, however, considering 70% of total plastic consumption is discarded as waste, thus approximately 5.6 million tons per annum (TPA) of plastic waste is generated in the country, which is about 15342 tons per day (TPD) ([31]). A survey was conducted to analyse demand break up of plastic by types showed in Fig. 1.

From this bar graph, it can be clearly seen that PVC, PP and HDPE contribute more toward the consumption of plastic. Consumption

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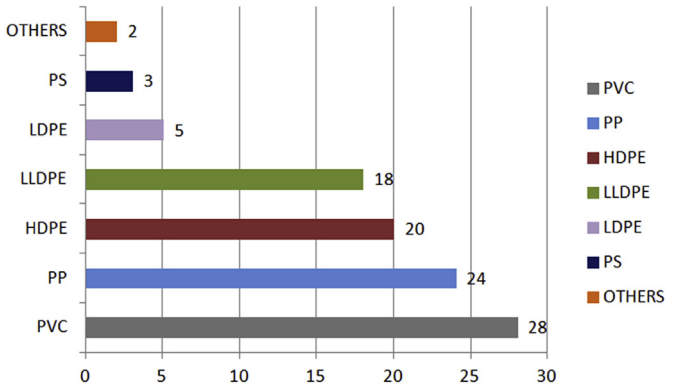

Fig. 1. Demand breakup of plastic.
(Source: Chemicals & Petrochemical Statistics, Analysis by Tata Strategic) [124]

of plastic is readily increasing due to various advantages coming from versatility, low cost and high chemical stability [96]. Polyethylene and polypropylene are a major component of plastic waste from domestic refuse [1]. More the consumption more is the need of recycling for reduction of use of virgin material. Major raw material for plastic commodities is HDPE (high density polyethylene)/ LDPE (low density polyethylene) and nylon. Plastic is a significant fraction of municipal solid waste and often consists of packaging waste and discarded tools and goods [10]. Because of this nature, it cannot be thrown in environment as such. This Figure is getting worse as new products are being introduced on a daily basis. This could be very dangerous for the environment and earth. The earth is also experiencing problems because of this plastic waste. In a study it was found that greenhouse gases are being emitted by fossil fuels as methane and carbon dioxide. It is worth noted that carbon emitted as methane gas has 21 times more global warming potential than being emitted as carbon dioxide [3]. Consumption and production of plastic polymer are based on demand and supply. But in India consumption and production of various plastic polymers is not equal. In India plastic consumption is 9.7 kg/person. Fig. 2 shows the report generated by Tata strategic on consumption and production of various plastic wastes.

It can be clearly seen from this data that consumption and production of polymer faces some huge gap. To fill these gaps usage of virgin material is getting high. Use of plastic product can only be reduced up to certain extent but use of new material for manufacturing can be reduced by using recycling and managing techniques. So many researchers have reported work on recycling

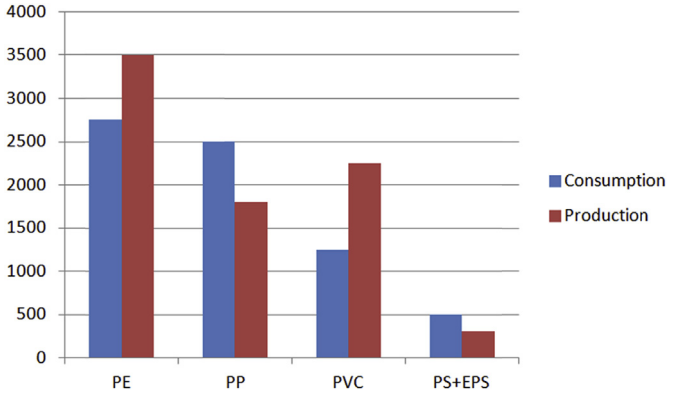

Fig. 2. Statistics on consumption and production of various plastic materials.
(Source: Govt. of India Statistics, Analysis by Tata Strategic)

and recovery of PSW. Central pollution control board, Delhi stated in a report that 90% of the PSW are recyclable. The 80% of post consumer based plastic is sent to the landfill, 8% is incinerated and 7% is recycled. Land filling of HDPE has serious consequences as production of GHG (green house gas) so, by using different methods PSW can be made suitable for further applications. Besides the environmental issues with land filling, the disposal of large amounts of remnant cloth is a huge waste of resources and energy [77]. By reinforcing different particles application domain of the recycled plastic can be increased. It can be used to make particle board as wood based particle boards are made compressing different layers by applying some glue or resin which contains urea formaldehyde and this formaldehyde has potential for increasing various kinds of diseases as well as cancer [11]. Deka and Maji [36] prepared wood plastic composite by blending of HDPE, polypropylene (PP), poly vinyl chloride (PVC), wood flour, modified MMT and glycidyl methacrylate (GMA). So recycled plastic may also be used as resin. Recycling of material can be done by various different techniques i.e. Primary, secondary, tertiary and quaternary [7]. With technological advancements in industry all types of polymers and metals can be recycled [83]. Some researchers have put down three methods of recycling of plastic. First is mechanical separation of plastic waste suitable for secondary use. The second method has two further sub parts; first is energy recovery by incineration and second way is pyrolysis for use as fuels or as polymer feedstock. The third method is taking polymer up to biodegradation level, but that highly depends on type and environmental conditions [56]. After this it can be concluded that plastics are majorly contributing towards municipal and industrial waste. In this paper effort has been put on for processing of the different plastic based materials and their recycling methods.

2. Global issues

PSW is a major contributing factor towards the waste generated on a global level. Disposal of polymer is becoming a global issue due to high production and consumption of polymer materials [108]. Many countries have their different waste generation level based on their income level become a serious issue for disposal and management of PSW. Management of waste is a complex process because of the requirement of various information from different sources such as influencing factors in waste generation, forecasts of vast quantities and reliable data [53]. In Eastern and Central Asia, the waste generated per year is at least 93 million tonnes. The per capita waste generation ranges from 0.29 to 2.1 kg per person per day, with an average of 1.1 kg/capita/day [91]. The Organization for Economic Co-operation and Development (OECD) is an international economic organization of 34 countries which includes AFR (Africa region), SAR (south Asia region), MENA (Middle East and North Africa), ECA (Eastern and Central Asia), LAC (Latin America and Caribbean), EAP (East Asia and the Pacific Region), OECD (Organization for Economic Co-operation and Development) founded in 1961 to stimulate economic progress and world trade. Fig. 3 shows the waste generation of various regions.

Solid waste management contributes less than 5% of global greenhouse gas (GHG) emission [20]. In response to growing concerns about the threat of climate change, international action aimed at reducing greenhouse gas (GHG) emissions is accelerating and the solid waste management sector is expected to contribute [132].

Further recycling of the PSW is limited to some no. of recycling cycles as after recycling product loses some of its properties like strength, stability etc. After a limited no. of recycling PSW only way to dispose off is land filling. But land filling leads to contamination of earth's surface. Further, land filling leads to emission of carbon

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