



A REVIEW ON CURRENT PRACTICES OF PLASTICS WASTE MANAGEMENT AND FUTURE PROSPECTS

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ABSTRACT

Inefficient solid waste management of plastics and polymeric materials is one of the global challenges leading to environmental deterioration. This challenge has brought alarming concern to minimize volume of such wastes released into the environment. The concern proposes a solution to the existing problems to some extent by reuse, recycling, and efficient conversion of waste materials into alternative application. Chemical and thermo-mechanical conversion of plastic wastes into energy and their biodegradation were taken into account. Consequently, some newly employed recycling and conversion techniques of plastic wastes, and possible future alternatives with recommendations are reviewed in this article.

Keywords: Plastic wastes, environmental concern, recycling, conversion, degradable materials.

INTRODUCTION

Synthetic and natural materials with carbon as an element that are composed of high-molecular-weight chains are the plastics, which was invented by Alexander Parkes in 1862 (Horodytska *et al.*, 2018). These synthetic polymers or semi-synthetic organic materials uses are rapidly increasing in our daily life. Improper management of plastics causes problems in many sectors including environment leading to global warming (Hoorweg & Bhadata, 2015). Due to their lightweight, durability, and versatility, they find a diverse range of applications such as various household appliances, corrosion-protected pipelines, furniture, packaging materials, containers, automobile and aircraft parts, 3D printing (Azeez, 2018), bio-adsorbents (Pokhrel *et al.*, 2019; Shrestha *et al.*, 2019), for medical purposes (Phaiju *et al.*, 2020), *etc.* Such applications of plastics and polymers led to their increased daily use in different forms and models.

The global plastic production increased by 250 million tons per year from 2009 to 2010 (Pandey *et al.*, 2016), which was increased to 320 million tons per annum in 2016 (Drzyzga & Prieto, 2018). China and European countries accounted for about 45 % of the global plastics production (i.e., 23.5 % and 21.5 %, respectively) in 2010 (Nath, 2014). According to the ICIMOD (2018), Nepal produces about 2.7 tons of plastic garbage daily, and its improper management creates lots of problems including environmental pollution.

Only one-third of the total plastic wastes generated are suitable for recycling, based on their material composition (Chamas *et al.*, 2020). Polypropylene (PP), polyethylene (PE), polystyrene (PS), polyvinyl chloride (PVC), *etc.* are

some of the recyclable plastics (SWMRMC/UN-HABITAT, 2008). However, most of the plastic wastes are incinerated at dumping sites (Rigamonti *et al.*, 2014). The debris can primarily be obtained from the large plastic processing and manufacturing industries, while commercial wastes are often produced from workshops, craftsmen shops, supermarkets, and wholesalers.

Some methods of plastic waste management

The uses of plastics are increasing day by day, and there is no solo method of their reuse, and disposal (Beyene, 2014; Dhokhikah & Trihadiningrum, 2012). The approach of management depends on the nature of plastics, and various countries have been practicing different methods. During the end of 20th century, China started buying plastic wastes for recycling purposes (Goncalves, 2018). In Austria, about 763,500 tons of plastic wastes were handled in 1994, and about 75 % of the amounts were buried in controlled landfills (Braunegg *et al.*, 2004). America, Canada, Germany, and Bangladesh are working for sustainable plastic waste management using landfilling, biological degradation, composting, and chemical degradation (Shah, 2008).

Nowadays, the use of different additives and hardeners with plastics decreases their biodegradability. Various countries have been practicing different approaches for solid plastic waste management, but none of these approaches are energy efficient and sustainable. It leads the undeveloped and developing countries manage their plastic wastes employing costly recycling or pyrolysis (catalytic and non-catalytic) processes. Nepal is following landfilling or dumping method (ICIMOD, 2018) to date and in the search of alternatives. It is an urgent need to collect plastics separately, unglued from other wastes such

as glasses, metals (electrical stuffs/electronics), and compostable solids, as practiced in developed countries.

Landfilling

Typically, 5 to 25 % (by weight) of plastic wastes is assumed to be potential for recycling purposes. However, information about the opportunities and challenges of plastic recovery, and recycling from the landfill sites are still missing (Cherubini *et al.*, 2009). Although a large fraction of the plastic wastes are subjected to landfill, such disposal is undesirable due to high cost, generation of greenhouse gases (methane, carbon monoxide, hydrogen sulfide, *etc.*), and poor degradability (Canopoli *et al.*, 2018). Uncontrolled fires and toxic emissions are common problems with poorly managed landfill sites that are considered as one of the sources of environmental pollution (Hidayah & Syafrudin, 2018).

Landfills are not the option with a complete solution of plastic waste management, though it provides disposal space for the residues and non-treatable solid wastes. In Nepal, the landfilling is a common process of the solid waste management. Okharpauwa landfill site at Nuwakot and Teku landfill site in Kathmandu are the major landfill sites in Nepal (ICIMOD, 2018). However, the management of such sites seems poor (Fig. 1), which badly affects in human respiration, optical vision, and skin allergy problems (Matlack, 2001). Additionally, the landfill areas/sites are inappropriate for construction works for about 50 years (ICIMOD, 2018).



Fig. 1. Photograph of one of the landfill sites in Nepal

A mechanical method of recycling

Mechanical recycling is a method of re-processing plastic wastes employing comparatively high energy along with additives producing recycled product (Ejlertsson *et al.*, 2003; Klink & Ham, 1982; Scaffaro *et al.*, 2019). This method comprises of collection, sorting out, and reprocessing of polymers into recycled products. Recycling of polyethylene terephthalate (PET) can be employed because the recycling rate of PET is higher in

comparison to other plastics (such as high-density polyethylene (HDPE), low-density polyethylene (LDPE), polypropylene (PP), *etc.*) recycled by this method (Hopewell *et al.*, 2009; Lu *et al.*, 2012).

Different spectroscopic and X-ray techniques are applied to sort out the plastic wastes (Ragaert *et al.*, 2017). Various procedures of recycling are adopted based on the origin and composition of the waste materials. It makes method of recycling comparatively expensive (Ragaert *et al.*, 2017). The crude shredder reduces the products to fist-sized particles, rotating drum washer, and fine shredder from washing reduces further in small-sized granules that are processed for further applications. The flow chart of the representative plant with the working principle of the mechanical recycling procedure is shown in Fig. 2. The float-sink separation, mechanical drier, and melt filter regranulation work to separate PP and PE as float, and the other polymers such as PET, PS, and PVC as a sink in this method (Scaffaro *et al.*, 2019; Ragaert *et al.*, 2017).

Thermal recycling/pyrolysis

Thermal/pyrolytic recycling is an alternative method for plastics waste management. Although the chlorine content in PVC and other plastics is responsible for the formation of dioxins and furans during thermal recycling, the relationship between plastics fed into an incinerator and the generation of dioxins and furans is still unclear (Yang *et al.*, 2001; Miskolczi *et al.*, 2004). The recycled PVC waste is used in plumbing pipes and fittings (Azeez, 2018). The sheets of PVC waste after thermal recycling are also used in various fields such as blister packages, packaging, construction, human rehabilitation, electronics, food trays, household applications, automotive and aerospace components, *etc.* (Azeez, 2018).

Thermal degradation of the polymeric materials which is also called thermal cracking or pyrolysis occurs in the absence or presence of oxygen (Alla *et al.*, 2014; Arandes *et al.*, 2003; Walendziewski & Steiningr, 2001; Demirbas, 2004; Panda *et al.*, 2010). This process is carried out at temperatures between 350 to 900° C. Hydrocarbon oils consisting of paraffin, isoparaffins, olefins, naphthenes, and aromatic compounds are produced from the process, however, no condensable high calorific value gas during this process (Niziolek *et al.*, 2017). It can also be carried out in presence of a catalyst (Al-Salem *et al.*, 2017; Iwaya *et al.*, 2002) with lower reaction temperatures (Gulab *et al.*, 2010). This advantage is further supported by comparative data of thermal and catalytic pyrolysis of microcrystalline zeolites presented in Table 1 (Almeida & Marques, 2016).

The commonly used catalysts in plastic waste pyrolysis include silica-alumina (Qiu *et al.*, 2017), zeolites (Cunliffe *et al.*, 2002), and MCM-41 (Marcilla *et al.*, 2003). Among numerous zeolites investigated in

polyolefin pyrolysis, Beta (He *et al.*, 2009), ultrastable Y-type (USY) (Boxiong *et al.*, 2007), ZSM-11 (Balasundram *et al.*, 2018) REY amorphous silica-alumina (ASA) (Zabeti *et al.*, 2012), Brookhart's iridium (III) (Monsigny

et al., 2019) are frequently used. The pyrolysis process of the polypropylene at the temperature of 450° C and pressure of 5 kgf/cm² is shown in Fig. 3.

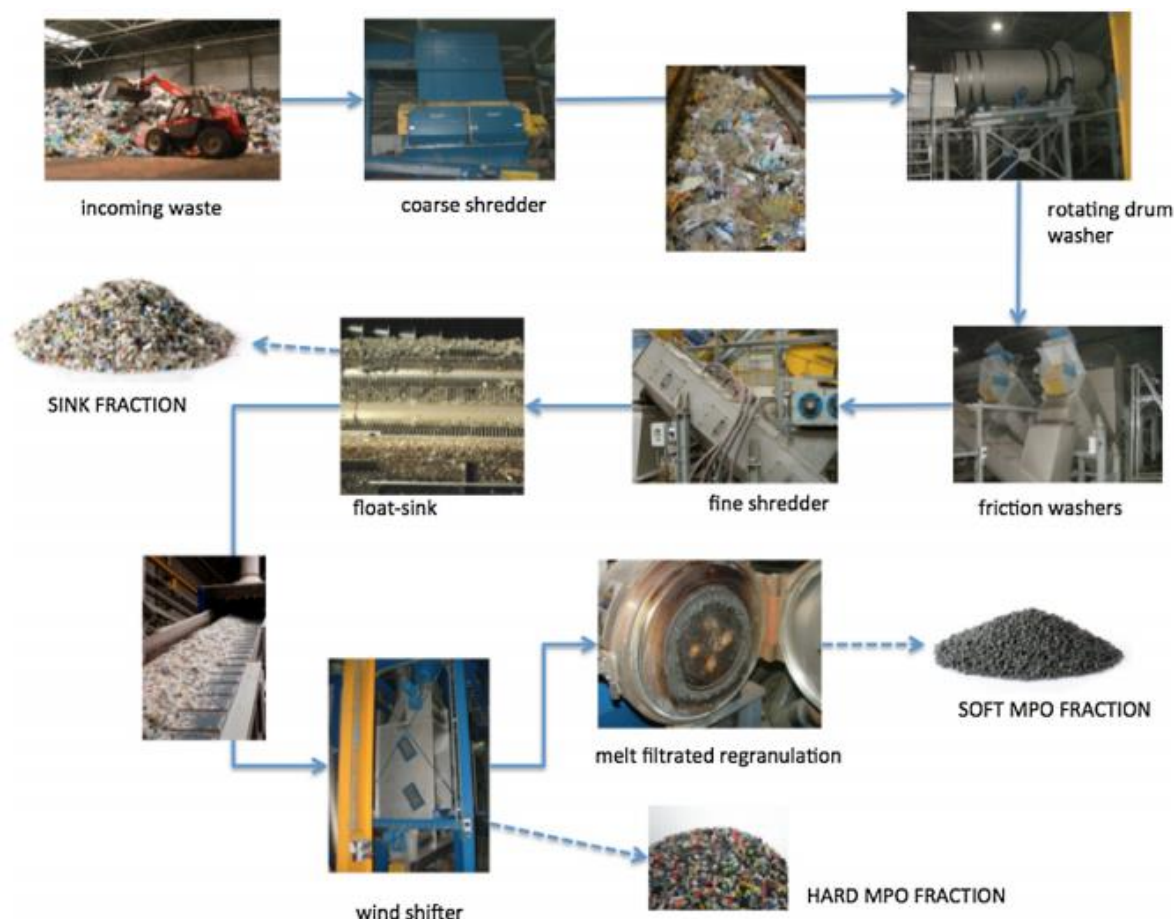


Fig. 2. The schematic flow chart illustrating the working principle of mechanical recycling (Ragaert *et al.*, 2017)

Table 1. Yield in thermal and catalytic pyrolysis of microcrystalline zeolite (ZSM-5)^a

Production yield (% wt.)	Thermal pyrolysis	Catalytic pyrolysis
Gas fraction	13.0	63.5
Liquid fraction total	84.0	35.0
C ₆ -C ₁₂	56.55	99.92
C ₁₃ -C ₂₃	37.79	0.08
>C ₂₃	5.66	0.0
Solid fraction	3.0	1.5

^aSource: Almeida & Marques (2016)

Similarly, the percentage of oil and wax obtained, reaction time, and calorific value of oil is shown in Table 2 (Sonawane *et al.*, 2015). It shows a lower calorific value and the yield of oil in comparison to natural zeolite as a catalyst (Sonawane *et al.*, 2015). The time required for the

pyrolysis of polymers in presence of natural zeolite is lower in comparison to its absence (65 min for catalyst and 90 min without catalyst) (Sonawane *et al.*, 2015).

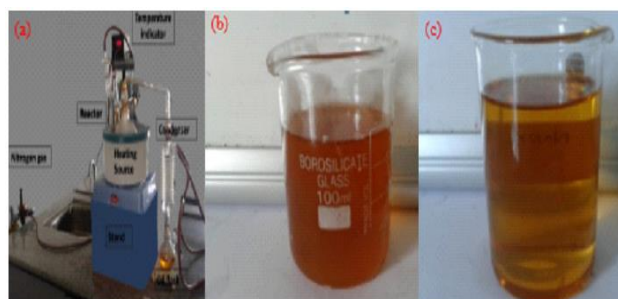


Fig. 3. (a) Experimental set up for pyrolysis of polypropylene (b) Oil obtained from pyrolysis without catalyst (c) Oil obtained from pyrolysis with 10 % natural zeolite as a catalyst (Sonawane *et al.*, 2015)

Chemical recycling

In this method, polymers are converted into their corresponding monomers (Achilias *et al.*, 2007) which are utilized as a feedstock for a variety of downstream industrial processes and as transportation fuels. It involves three different processes such as depolymerization, partial oxidation, and chemical cracking for recycling (Cunliffe *et al.*, 2003). In depolymerization, polymeric wastes are converted into sulfur-free liquid energy carriers by chemical recycling (Aguado *et al.*, 1999). These installations (80-85 %) allow the recovery of the energy contain in the plastic wastes. It is reported that 1 mg of depolymerized products of mixed plastics can carry 4.5 to

5.9 calories of energy. Hence, this technology of conversion of plastics into alternative fuels is considered as a high-efficiency value and eco-friendly technology (Wolosewicz-Glab *et al.*, 2017; Sakata *et al.*, 1999). Condensation polymers such as polyamides, polyesters, nylons, polyethylene, terephthalate, *etc.* can be depolymerized *via* reversible synthesis reactions to initial di-acids and diols or diamines (Shabtai *et al.*, 1997). The polymers are converted into their raw monomers *via* depolymerization reactions such as alcoholysis, glycolysis, and hydrolysis, *etc.* (Kaminsky & Zorriquetta, 2007).

Table 2. Percentage yield of oil and wax obtained without catalyst and 10% natural zeolite (Sonawane *et al.*, 2015)

PP material (200 g)	Oil (%)	Wax (%)	Reaction time (minutes)	Calorific value of oil (KJ/Kg)
Without catalyst	80.82	18.64	90	25794
With 10 % Nz catalyst	86.41	11.34	65	27167

Partial oxidation takes place in presence of oxygen or steam during which polymer wastes undergo combustion followed by the formation of light hydrocarbons, oxides of nitrogen, sulfur oxides, and dioxins (Shabtai *et al.*, 1997). Similarly, other cracking processes such as hydrocracking, thermal cracking, and catalytic cracking are also reported (Beneroso *et al.*, 2015). Typical feeds used in them include polyethylene, polyethylene terephthalate, polystyrene, polyvinyl chloride, and mixed polymers, polymer waste from municipal solid waste and other sources, polymers-coal co-mixture, refinery oils-coal (alone or co-processed) mixture, *etc.* (Dwivedi *et al.*, 2019).

Biological recycling

Biological recycling is the process in which microorganisms (bacteria, actinomycetes, and fungi) degrade the plastics, and waste polymeric materials producing CO₂, H₂O, and microbial biomass, as the final products (Labelagr, 2006; Kujawa *et al.*, 2007, Cerqueira *et al.*, 2016). Dominant groups of microorganisms and the different pathways (aerobic and anaerobic) associated with polymer degradation are often determined by the environmental conditions (Fesseha & Abebe, 2019; Singh & Rawat, 2019). The microorganisms such as Gram-positive and Gram-negative bacteria as well as a few species of fungal origin like *Aspergillus* are particularly involved. Species of microbes like *Streptococcus*, *Staphylococcus*, *Micrococcus* (Gram-positive), *Moraxella* and *Pseudomonas* (Gram-negative), and species of fungi (*Aspergillus glaucus* and *Aspergillus niger*) are associated with biodegradation of plastics. Besides *Pseudomonas fluorescens* B-22, *Phanerochaete chrysosporium*, *Rhodococcus ruber*, *Penicillium oxalicum*, *Bacillus cereus*, *etc.*, are involved in breaking down the plastics/polymers such as polyvinyl chloride, nylon,

polystyrene, polyethylene, and polypropylene respectively (Danko *et al.*, 2004; Iiyoshi *et al.*, 1998; Mor & Sivan, 2008; Ojha *et al.*, 2017; Helen *et al.*, 2017).

Biodegradation and composting are also used almost as a synonymous terms in biological recycling but not the same, and the exact mechanism of biological recycling is still unknown and yet to be optimized. Although there are many possible predicted mechanisms of bio-recycling, a simple one is shown in Fig. 4 (Fesseha & Abebe, 2019). During biological recycling of polymeric solid waste products, the formation of methane, CO₂, H₂O, metabolic products such as sugars, *etc.*, are commonly formed which are useful for plant growth. The composted final products of waste plastics are used as fertilizers. Bio-based plastics such as poly-lactic acid, polyesters, polyhydroxy butyrate, *etc.*, are hydrolyzed and degraded more easily as compared to petro-based plastics such as polyethylene, polystyrene, polypropylene, *etc.* Hence, the research on bio-based polymeric materials with their end products as fertilizers has flourished in recent years (Fesseha & Abebe, 2019; Ciriminna & Pagliaro, 2020).

The microorganisms such as *Comamonas acidovorans*, *Fusarium solani*, *Phanerochaete chrysosporium* contribute to degradation of plastics in presence of enzymes such as lipases, cutinase, and manganese peroxide (Table 3). Plastics undergo biodegradation producing biofilms, oligomers, monomers, and substrates. Some plastics and corresponding degrading microorganisms are presented in Table 3. Polypropylene can also be degraded by its exposure to UV radiation from sunlight and it can also be oxidized at high temperatures. Different characterization techniques such as differential scanning calorimetry (DSC), Fourier transform infrared spectroscopy (FTIR), nuclear magnetic resonance spectroscopy (NMR), X-ray diffraction (XRD), contact angle measurements, X-ray

photoelectron spectroscopy (XPS), water uptake experiment, etc., are applied to assess the biological

degradation of plastics (Abdelaal *et al.*, 2014).

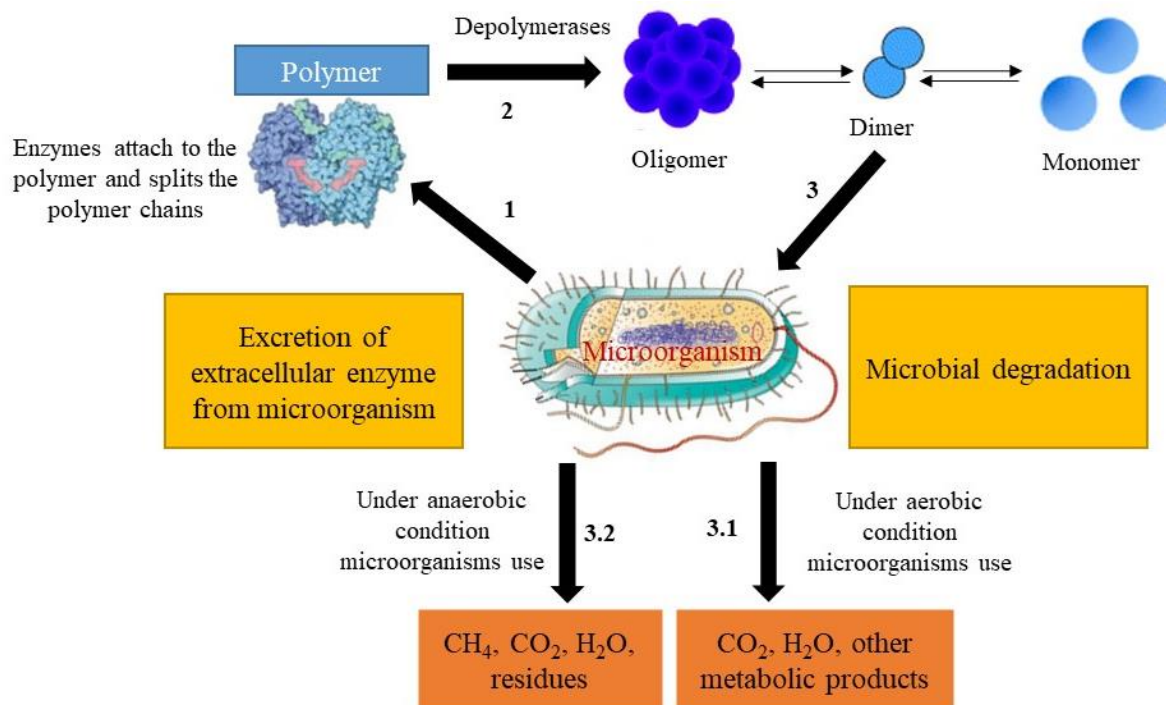


Fig. 4. Biodegradation mechanism of plastics under aerobic and anaerobic conditions (Fesseha & Abebe, 2019)

Table 3. Microorganisms and corresponding enzymes for degradation of some plastics

Plastics	Microorganism	Enzyme	Simple form	References
Polyethylene	<i>Penicillium oxalicum</i> & <i>Penicillium chrysogenum</i>	-	Biofilm	(Ojha <i>et al.</i> , 2017)
Polycaprolactone	<i>Fusarium solani</i>	Cutinase	-	(Murphy <i>et al.</i> , 1996)
Nylon	<i>Phanerochaete chrysosporium</i>	Manganese peroxidase	Oligomers	(Iiyoshi <i>et al.</i> , 1998)
Polyvinyl chloride	<i>Pseudomonas fluorescens</i> B-22	-	Substrate	(Danko <i>et al.</i> , 2004)
Polystyrene	<i>Rhodococcus ruber</i>	-	Biofilm	(Mor & Sivan, 2008)
Polypropylene	<i>Bacillus cereus</i> & <i>Sporosarcina globispora</i>	-	-	(Helen <i>et al.</i> , 2017)
Polyurethane	<i>Comamonas acidovorans</i>	Lipases	-	(Howard, 2011)

Nowadays, researchers and scientists are preparing polymeric materials using naturally available and degradable materials to substitute petro-based plastics to bio-based to some extent. Natural fibers-filled polymer composites have low mechanical and optical properties; however, they are more brittle in comparison to petro-based polymers/plastics (Bhandari *et al.*, 2019). The polymer films such as cellulose, polylactic acid, polycaprolactone, etc., degrade faster in the soil compared to polyethylene, polyvinyl chloride, polystyrene (Bhandari *et al.*, 2021a, 2021b).

Plastic waste management during COVID-19 period

There is maximum use of masks, gloves, and personal protective equipment (PPE) during COVID-19 by health workers, patients, and others (Prata *et al.*, 2020; Rothan & Byrareddy, 2020). These materials require proper management and disposal from an environmental point of view (Prata *et al.*, 2020; Fan *et al.*, 2021). Fig. 5 presents the schematic information and risks about plastic wastes management during the COVID-19 period (Fan *et al.*, 2021).

Fig. 5 represents the waste amount, change in waste amount, disposal rate, and timing (temporal), distribution (spatial), and infection risk (Fan *et al.*, 2021). An

improper management of the wastes may be a threat associated to COVID-19 infection (Bhandary *et al.*, 2020; Tuladhar, 2020).

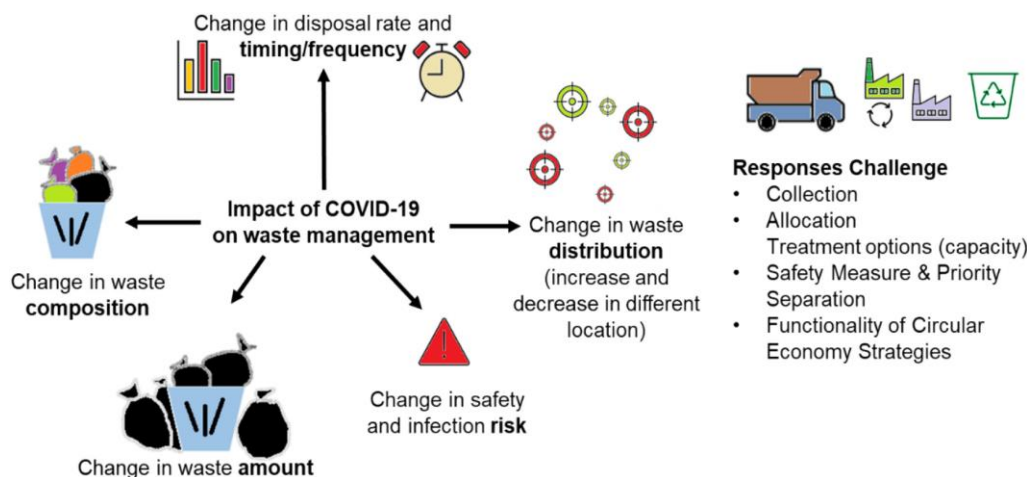


Fig. 5. Waste management scheme during COVID-19 period (with the waste amount, change in waste amount, disposal rate and time, distribution, infection risk impact, and challenges) (Fan *et al.*, 2021)

Synthesis of carbon dots (C-dots)

Carbon dots are widely used in photo-catalysis for the decomposition of environmental pollutants, sensors and solar cells, bio-imaging, *etc.* (Aji *et al.*, 2018). Nowadays, plastic wastes are also used for the preparation of C-dots. Carbon chains present in plastics (both bio and petro-based) undergo rearrangement during polymerization and carbonization processes to form C-dots (Kumal *et al.*, 2018, Lauria & Lizundia, 2020; Hu *et al.*, 2021). C-dots have a tiny particle size (<10 nm) and possess fluorescence.

Polyethylene (PE), polystyrene (PS), polypropylene (PP), polyvinyl chloride (PVC), polyvinyl alcohol (PVA), polyethylene glycol (PEG), polyacrylic acid (PAA), polylactic acid (PLA), and some of the polymeric species are used as raw materials for the synthesis of C-dots (Hu *et al.*, 2021). Similarly, Aji *et al.* (2018) synthesized C-dots nanoparticles using waste plastic bags of polypropylene (PP) at 200 °C, 250 °C, and 300 °C. During the synthesis of C-dots from solid wastes, biological by-products are formed. Hence, the synthesis of C-dots from polymers is also an environment-friendly method for plastics waste management (Lauria & Lizundia, 2020).

Economic and environmental aspects of plastic waste management

The economy and technology play a vital role in plastic recycling and management (Renzini *et al.*, 2009; Aho *et al.*, 2007). Plastic recycling is further divided into material recycling and energy recovery (Pendern & Yang, 2019) for which mechanical recycling is mostly preferred.

Nowadays, researchers have developed many techniques of modification of plastic wastes for their multiple-use and proper management. There is formation of alternative useful materials such as plastic bricks, road construction materials, *etc.*, from the waste materials (Sasidharan *et al.*, 2019). The development of such techniques helps to minimize the mass of plastic wastes releasing into the earth's crust as well as reduces the cost of useful materials production (Brasileiro *et al.*, 2019; Horvath *et al.*, 2018; Siddique *et al.*, 2008).

Different countries such as India, the UK, the Netherlands, Ghana, Ethiopia, and South Africa have implemented the policy of using plastic wastes for road construction (Sasidharan *et al.*, 2019). The waste plastics have been used in bituminous road construction, and addition at small amount (~5-10 wt. %) helps in significant improvement of strength, stability, fatigue life, and other desirable properties, longevity, and pavement (Sasidharan *et al.*, 2019). Nepal has also developed some techniques (plastic fuel production, plastic tar for road construction) to utilize plastic waste and contribute to the control of environmental pollution (The Himalayan Times, 2018). It is almost impossible to ban plastic production immediately due to which sustainable plastic management is an urgent task.

Current situation of plastic waste management in Nepal

Daily use of plastic bags in Kathmandu (capital city) of Nepal is around 4,700,000 to 4,800,000 pieces (SWMRMC, 2004). In Nepal, 16 % of urban waste comprises plastics, which is 2.7 tons of plastic garbage production daily (JICA/MLD, 2005). The daily plastic

waste production in Nepal has increased continuously day by day (ICIMOD, 2018). Generally, solid wastes produced from daily life comprise of 56 % organic wastes, 16 % plastics, and 16 % paper products, 3 % glass, 2 % metals, 2 % textiles, 1 % rubber and leather, and 4 % others (Anderzen & Bles, 2003). With the compost plant located at Teku, Kathmandu (capacity: 3 tons) closed in 1992, consequently increased, waste volume in the Gokarna landfill site, Kathmandu. Lack of roads or other infrastructures at the site resulted in vehicles dump waste near the Leachate pond. Due to inadequate compaction, a big landfill slide in 1992 covered the entire Leachate pond with waste (ADB, 2013). The current situation of waste plastics collection around the roadside in Kathmandu valley was shown in Fig. 6.



Fig. 6. Photographs of (a) unmanaged plastic waste in roads (b) waste piled at Teku landfill station, Kathmandu

Flash floods are common in Nepal due to plastic wastes clogging the rivers and streams in the mountains and hilly regions. The impact of what we do in the mountains is also felt downstream (Shrestha, 2010). They are neglected due to the absence of efficiency and inadequacy of the services. The container service, door-to-door collection, and roadside pick-up from open piles or containers are the types of collection service generally practiced in Nepal. The door-to-door collection is practiced by 24 municipalities; roadside pick-up from open piles is a prevailing practice, with 49 municipalities counting on plastics waste management (Babayemi *et al.*, 2019).

Nepal Government together with corresponding ministries and authorities should bear the responsibilities regarding solid waste management (CBS, 1996). A huge volume of waste generated with practice of open burning, waste-mixing practice, lack of reduction, reuse, and recycling and delayed and incomplete construction of a new landfill, informal and profit-oriented involvement of private waste collectors, were reported (Tuladhar & Bania, 1997).

Degradable/compostable plastics and their composite materials: an alternative

Natural polymers, fibers, bio-plastics, biomaterials, green materials, degradable plastics, *etc.*, are the possible

alternatives to address all of the above-mentioned challenges. However, the properties of these polymers and materials cannot be perfectly suitable for applications. Therefore, the development of applications-oriented eco-friendly novel materials (such as composites, blends, *etc.*) based on these benign polymers can be a solution. An immediate action to collect the plastics waste scientifically and manage with best alternatives besides landfilling is needed. In India, thousands of kilometers of road have been constructed from waste plastics in recent years.

Furthermore, polylactic acid (PLA), starch, cellulose, polyglycolide (PGA), natural fibers, *etc.*, are currently used as natural polymers (Adhikari *et al.*, 2012a, 2012b; Bhandari, 2017; Mohanty *et al.*, 2000; Bhandari *et al.*, 2018; Wittel *et al.*, 2003). Similarly, polybutylene adipate terephthalate (PBAT), polyhydroxyalkanoates (PHA), poly(alkylene dicarboxylate), *etc.*, are degradable polymers, i.e. both on the soil surface and under burial (Mohanty *et al.*, 2000). They undergo both enzymatic and chemical hydrolysis (degradation) (Wei *et al.*, 2018). Biopolymers and bioplastics are degraded by UV radiation and microorganisms. Thus, from the economic and ecological/environmental point of view, plastic reuse, recycling, and their substitution by natural and degradable polymeric materials is an alternative to reduce non-degradable petroleum-based commodity plastics.

CONCLUSION

Current data shows a continuous growth of production and consumption of plastics/polymeric materials that cannot be controlled drastically. However, a huge amount of plastic wastes produced can be managed with suitably designed ecological and economical methods. Conversion of waste plastics into hydrocarbon fuel seems an excellent option for partial substitution of petroleum products. However, the economic perspective is to be considered and the technique has not been successful till now. The analyses of the above described different methods indicate that mechanical recycling can be an appropriate method for waste plastic management in the present context of Nepal.

Furthermore, the most common and daily used plastic products in Nepal are small to large plastic containers, packaging materials, polyethylene bags, thermosets, cables, insulating covers, *etc.* Most of these materials can be substituted using degradable polymers and their composites filled with degradable/compostable natural materials. Reducing the use of plastics and polymeric materials, reusing them many times, collecting the plastics in dustbins/drums separately, recycling as much as possible are the short-term steps to be implemented immediately. The promotion of research on degradable polymers, and the campaign for change in human habitual behavior on plastics use by proper education from schools

to universities are necessary for long-term policies to combat polymeric wastes in the future. The use and promotion of degradable polymeric materials as a frontline state policy in this regard is recommended.

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