Poll Res. 41 (1) : 202-209 (2022)

ISSN 0257–8050
DOI No.: http://doi.org/10.53550/PR.2022.v41i01.029

A REVIEW: COMPARISON BETWEEN PRODUCTION OF CONVENTIONAL PLASTICS AND CACTUS PLASTICS: NON-TOXIC TO PLANTS AND ANIMALS

VINOD KUMAR KONDREDDY, KRISHN KUMARI N. GURU*, PADMANABHA REDDY, YIRAGAMREDDY, NARESH BABU CHILAMAKURU AND TRIVENI SINGIRISETTY

[1]Department of Pharmaceutical Analysis, Raghavendra Institute of Pharmaceutical Education and Research (RIPER) – Autonomous, K.R. Palli Cross, Anantapur 515 721, Andhra Pradesh, India

(Received 28 April, 2021; Accepted 14 June, 2021)

ABSTRACT

Globally, plastics have vast applications, and day-to-day life has been growing in plastic production and use from the 1950's till now. These plastics were made from different polymers, chemicals, solvents; adhesives, etc. are very dangerous to the humans and animals by pollution caused by them. During production and decaying of plastics (takes nearly hundred to thousand years) releases various chemicals leads to plastic pollution, ozone layer depletion, rise in chemical gases in the environment etc. To overcome these pollution crisis, Dr. Sandra Pascoe Ortiz have started production of plastics with prickly pear cactus plant. This material is completely non-toxic, and all the materials used could be ingested by animals or humans, which do not cause any harm. The cactus plant is widely spread by propagation technique in deserts belonging to the US Department of Agriculture' (USDA) Hardiness zones (zone 2) and easily cultivated nearby homes. This prospective study states that the cactus plant material is the best material for the production of plastics when compared with other materials with advantages of rapid biodegradability (3 months or within a few weeks in water), nontoxic and also non-risk to humans or animals.

KEY WORDS : Plastics, Polymers, Additives, Cactus plant, USDA, Biodegradable.

INTRODUCTION

One of India's increasingly growing industries is the plastic industry. In the 1950s, mass manufacturing of plastics began, making them accessible to consumers in a number of contexts (Kumar, 2020). The reasons for popularity for using the plastic bags are light weight, resistance to degradation (by chemicals, sunlight and bacteria), durability and above all low cost (Geyer, 2020). Many chemicals / polymers are extracted from non-renewable crude oil and some of those are used in the manufacturing of plastic materials (Maraveas, 2020). The main sources of plastic entering the atmosphere are land and ocean sources, with the most important contributors being domestic, agricultural and fishing activities (LI, Tse *et al.*, 2016). The polymers in plastic materials are toxic, absorbent and cannot protect the atmosphere from persistent organic contaminants (POPs) (Kumar, 2020) and it is estimated that the time taken for plastics to degrade in the atmosphere was hundreds to thousands of years (Bejgarn, MacLeod *et al.*, 2015). Several toxic chemicals are leaked from plastics during the manufacture, use, disposal (Lithner, Larsson *et al.*, 2011), during degradation process and that have a wide negative effect on biota (Andres, Fielding *et al.*, 1999). The packing of hot edible products in plastic bags allows the migration of harmful chemicals into the food products (Ignatyev, Thielemans *et al.*, 2014). In addition, packaging with plastics may include residues of substances used in the production process such as solvents, accidentally added substances, impurities, oligomers or degradation items *et al.*, 2019).

Globally, plastic waste litters marine environments, most of which are microscopic and

eaten by a wide number of organisms (Joseph, Kumar *et al.*, 2016). Beaches are particularly vulnerable to micro-plastic emissions in highly protected natural areas, with contamination levels reaching with greater concentrations(Baztan, Carrasco *et al.*, 2014). Also, during short-term water leaching, hazardous chemicals are leached mostly from plasticized polyvinyl chloride (PVC) and epoxy products (Lithner, Nordensvan *et al.*, 2012). In the *Daphnia magna*, plastic effluent has earlier been shown to cause deleterious effects (Gewert, Plassmann *et al.*, 2015). Artificial sunlight has regularly leached and weathered plastics from commercially accessible items (Bejgarn, MacLeod *et al.*, 2015). No exposure has been paid to the more widely exposed women working in the plastics industry to the adverse effects of chemicals found in different plastic consumer goods (DeMatteo, Keith *et al.*, 2013).

Plastic polymers and their effects during and after production

Polymers are massive organic chemical compounds with atomic mass units of thousands to millions, similar to long chains consisting of a series of intertwined ties that seem infinite (Lithner, Larsson *et al.*, 2011). The polymers which are mostly used in the production of plastics were polypropylene (PP), low density polyethylene (LDPE), linear low-density polyethylene (LLDPE), high density polyethylene (HDPE), polycarbonate (PC), polyethylene terephthalate (PET), polyvinyl chloride (PVC), acrylonitrile butadiene styrene (ABS), polystyrene (PS) (Koshti *et al.*, 2018).

Polystyrene (PS)

Polystyrene is commonly used for packaging many food items, such as beef, dairy products and bakery products, in different types (Thakur, Verma *et al.*, 2018). The presence of styrene monomer in foods can cause problems with cancer, haematology, cytogenetics and neurotoxicity (Pilevar, Bahrami *et al.*, 2019). Styrene inhalation contributes to an elevated level of oxidative stress, which is meant to cause lung damage (Sati, Khaliq *et al.*, 2011).

Bisphenol A(BPA)

Very low doses of BPA exposure are associated with severe problems such as tumours, lack of exercise, neuropsychiatric disorders and endocrine disruption. (Vogel, 2009). It has oestrogenic activity and is extremely poisonous to marine species (Scarascia-Mugnozza, Sica *et al.*, 2011). A climate (aquatic environment, air and soil) may be another cause of BPA exposure, but perhaps the top most priority of environmental contamination seems to be food (Kang, Kondo *et al.*, 2006).

Polyvinyl chloride (PVC)

Among all polymers, polyvinyl chloride has been mainly involved in creating the most serious fire fighting issue today since it releases hydrogen chloride gas while burning (Endo 2002). One hundred and seventy fire fighters who encountered toxicity symptoms were examined from 1970 to 1975 (Dyer and Esch, 1976). Infusion lines can leach plasticizers in significant quantities and are therefore a candidate material for long-term total parenteral nutrition (TPN) hepatotoxic effects (Loff, Kabs *et al.*, 2000). The type widely used for blood transfusions, serum-containing solutions perfused by polyvinyl chloride administration tubing, becomes highly toxic to heart cells isolated in tissue culture (DEHAAN 1971). Polyvinyl chloride biodegradation that has been buried under the soil for more than 32 years (Otake, Kobayashi *et al.*, 1995).

Polyethylene (PE)

Scattereda symptomatic lesions, scattered symptomatic lesions without functional disability, generalized functional impairment eruptions, and erosive or ulcerated lesions are caused by polyethylene (Mak, Yeung *et al.*, 2019). These signs are classified as follows by different grades:

- Asymptomatic, moderate erythema, swelling or desquamation are suggested by Grade I (Gao, Liu *et al.*, 2019).
- Painful erythema, swelling, and desquamation of Grade II which do not prohibit regular physical activity (Kumar, Kanna *et al.*, 2017).
- Blistering, ulceration, or swelling in Grade III interferes with daily life, including the ability to wear clothes (Pittura, Avio *et al.*, 2018).
- Grade IV Infection or bedridden condition caused by diffuse or local blistering and ulceration (Heindler, Alajmi *et al.*, 2017).

Analysis of the tissue oxidative stress marker found that the development of lesions was associated with increased oxidative stress (Çobanoðlu, Belivermiþ *et al.*, 2021). In addition, a comparison of the levels of adverse effects showed that micro plastic beads (MPs) were more harmful to the eyes and reproduction than the kidneys or development (Chisada, Yoshida *et al., 2020)*.

Polyethylene terephthalate (PET)

Polyethylene terephthalate and glass are also commonly used in bottled drinking water products (Parolini, De Felice *et al.*, 2020). PET bottles also increased the release of formaldehyde, acetaldehyde and antimony (Sb), resulting in metal toxicity due to bottle leaching (Bach, Dauchy *et al.*, 2014). It takes about 1000 years for plastics to decompose efficiently (Koshti, Mehta *et al.*, 2018).

The different polymers used for different plastic materials which may use in several purposes like plastic packing, construction,textiles, consumer products, transportation, electrical, industrial machinery (Feldman and Barbalata, 1996).

Effects on human health

The production of plastics has undergone dramatic changes over the past 50 years (Verleye, Roeges *et al.*, 2001). Diverse chemicals are released in the manufacture of plastics (Mangaraj *et al.*, 2019). SO_2 is released as crude oil is refined (4 percent of which is added to plastics), leading to acidification (Mulder, 1998). There is a chance of fire in plastic manufacturing, which can also cause toxic emissions, such as hydrochloric acid vapours produced by PVC burning (Mulder, 1998). There are adverse developmental implications of overdoses of BPA during pregnancy or lactation, including decreased survival, birth weight, early growth of offspring and delayed puberty in male and female rodents (Koch and Calafat, 2009). Chemicals found in plastics can theoretically migrate in contact with the polymer and can also migrate to the surface slowly inside the plastic (Hahladakis, Velis *et al.*, 2018).

Regulations / summit meetingsfor plastic pollution control

- India hosted the 43rd World Environment Day in2018, focusing on disposable or single-use plastics with the theme 'Beat Plastic Pollution' (Godswill and Godspel, 2019).
- Article 210 requires States to develop a framework for 'preventing, reducing and controlling dumping pollution of the marine environment' (Xanthos and Walker, 2017).
- The Central Pollution Control Board and the numerous state Pollution Control Boards enforce the Environmental Protection Act, 1986 (Kumar, 2020).
- Part XII (Articles 192-237) of the United Nations Sea Law Convention (UNCLOS) is dedicated to the safeguards and preservation of the biosphere (Vince and Hardesty 2018).
- Kenya, Tunisia joined African League in2017, which prohibits the use of plastic packages (Godswill and Godspel, 2019).
- In 2008, the National Oceanic and Atmospheric Association (NOAA) hosted their first workshop on micro plastic pollution, gaining international awareness for the issue.
- The Regulation establishes 'Specific limits of migration' These are established on the basis of toxicants for single element by European Food Safety Authority (EFSA) (Hahladakis, Velis *et al.*, 2018).
- US misgivings about contaminants in synthetic materials have always been asserted in the headline of an April 14, 2008, front feature article in the Washington Post (Vogel, 2009).

Alternative to conventional plastics - cactus biodegradable plastic

Cactus plastics, which are biodegradable and non-toxic to humans, animals, and are produced in order to overcome the chemical pollution crisis during plastic production, usage, and degradation. An investigator Sandra Pascoe, has embarked on a

Table 1. Effects of plastics on human health

Plastic	Effects on human health
Polyvinyl chloride	Cancer, birth defects, failure of vision, ulcers
Polycarbonate	Cancer, obesity, hyperactivity, diabetes
Polystyrenes	Eye, nose and throat irritation, dizziness
Polyethylene	The carcinogen of humans
Formaldehyde urea	Birth defects, carcinogens, and genetic changes
Foam polyurethane	Coughing, bronchitis, skin and eye problems
Acrylic	Vomiting, diarrhoea, nausea, tiredness, and headache
Tetrafluoro ethylene	Difficulties with breathing
Phthalates	Endocrine disruption, asthma, hormonal changes

mission to create bioplastics through attempting to make Ficus juice. A researcher has developed a packaging material that is made from the plant and provides a promising solution to one of the greatest plastic effluences in the world (Rodriguez-Felix, 2000). It is non-toxic product to the both humans and animals even ingestion also and do not cause any harm. The differences between conventional plastics and cactus biodegradable plastic were showed in Table 2.

DISTRIBUTION

Prickly pear, belongs to a group Cactaceae and contains approximately 130 taxa and nearly 1500 primates (Bach, Dauchy *et al.*, 2014). A tree native to Mexico is the *Opuntia Ficus-indica*. In arid semi-arid regions, it has the particularity to grow (Silva, Melo *et al*., 2017) and It has been distributed through various places, growing conditions and is a drought-tolerant crop (Mayer and Cushman, 2019). By planting the cactus pads in black soil nearby homes, it can be easily cultivated anywhere.In farmlands and in the gardens of residential villages, crops are grown (Pimienta-Barrios, 1994).

MATERIALS AND METHODS

Collection

Nopal cladodes were collected from the INRA Set tat Morocco regional centre experimental station (Allai, Karym *et al.*, 2017). The nopal's fleshy stalks are long thin harpoons, which are likely to be 7 to 10 mm tall (Agarwala, Agarwala *et al.*, 2008). Experts sliced cartel prickly pear buries on the secondary cladode, more than four years without previous cuts (Silva, Melo *et al*., 2017). Using cutters, cactus pads or leaves are inserted. The main precaution taken during the collection of pads to avoid thorns is wearing hand gloves.

Extraction method

Wash the pads beneath running water: Lightly scrub the pads with a potato brush under lukewarm water (Barbera, Inglese *et al.*, 1995). Scrubbing the pads removes any sand or dirt from the exterior of the pad, but scrubbing too hard may pierce the pad and cause some of the juice to leak out prematurely (Blanco-Macías, Valdez-Cepeda *et al.*, 2000). Place the pad on a flat counter: Cut away any bruised parts of the pad using a small, sharp knife (Gebremariam, Melaku *et al.*, 2006). Transfer the pads to a large bowl: The bowl should be large enough to fit the pads, and it must also have a large enough mouth for you to work with the pads inside the bowl (Corrales-García, 2007). Crush the pads: Use the flat top of a hammer-style meat tenderizer or other flat kitchen utensil (Dev, Singh *et al.*, 2018). Press the tenderizer against the pads, crushing the juice out. Continue pressing until the pads are thoroughly broken and removed of most of their juice. Strain the juice out: The pad pieces should be relatively large, so the juice should not be too pulpy (Salem, Nefzaoui *et al.*, 2002). Simply pour the juice through a wire mesh strainer and into a separate glass or bowl, allowing the solid portions to remain trapped on the other side of the strainer(Nolen, Allen *et al.*, 2017).

Production

Mixed with non-toxic additives, cactus juice is stretched to produce sheets that are coloured with pigments and folded to form various packaging types (Goldman, Vinokur *et al.*, 2004). The formula is then dried to produce thin sheets of plastic on a hot plate (Nharingo, Zivurawa *et al.*, 2015).
Non-toxic additives include glycerine, natural proteins, and in some cases natural dyes are used for consistency of the product (Atti, Mahouachi *et al*., 2006). In the fight to preserve the environment, Pascoe says her new material would be no more than a "drop in the ocean".

Table 2. Conventional plastics VS cactus plastic

Characteristics	Conventional plastics	Cactus plastic
Decaying time	100-1000 years or above	Few weeks to few months
Ingestion by aquatic organisms	Harmful	Not harmful
Usage of chemicals	More	Very less
Toxicity	Superfluous toxic to humans and animals	Non-toxic to humans and animals
Production	Minor scale to large scale	Minor scale and large scale are in processing
Additives used	Less toxic	Non-toxic

RESULTS AND DISCUSSION

In traditional folk medicine, prickly pear has been used due to its role in the diagnosis of illness including inflammatory conditions, biliary dysfunctions (Bach, Dauchy *et al.*, 2014). In many countries around the world, through antioxidant measures and also used in the treatment of High blood pressure, pulmonary tissue, scorches, eczema and stomach problems (Das, Sarmah *et al.*, 2015).

Advantages of cactus plastic compared to other plastics

Production of plastics is very easier when compared to other conventional plastics (Andrady and Neal, 2009). Decaying the plastic in the earth or in marine sources within few weeks, and a detail decaying time of various plastic materials is fast (Grigore, 2017). Processing and preparation of cactus juice user simpler methods like centrifugation and filtration (Guillet, Huber *et al.,* 1992). Additives added to cactus juice is non-toxic and it is not harmful to humans and animals (Pritchard 2012).

CONCLUSION

Globally, Plastic production and usagefrom past to present has increased gradually. Manufacturing of plastics with polymers, additives, adhesives is very toxic to humans and animals. Degradation of those manufactured materials takes place from 100 to 1000 years. Replacement of those materials from toxic to non-toxic was succeeded by Dr. Sandra Pascoe, a Mexican researcher using cactus plant juice. If any one of its material makes its own way into the ocean, it won't be a problem if eaten and even if not eaten, it will soon enough dissolve and disappear. The investigator study says that the material begins to break down in soil for a month and when left in water, it breaks down in a matter of days. I conclude that the polymer made with cactus plant is very beneficial to the world which decreases the pollution in the biosphere, reduces the hazardous chemicals, decreases allergic diseases, respiratory disorders, psychotropic abnormalities, convulsions eczema, etc..7

Outlook

This research work should be elongated from small scale to large scale. The usage of plastic difference should be well known to the public which is hazardous or not. By this way, we can prevent pollution and environment from toxic chemicals. Depletion of ozone layer can be prevented by less pollutants. These plastic materials should be distributed widely from one country to all other countries.

ACKNOWLEDGEMENT

I would like to express my special thanks of gratitude to my professors for their able guidance and support in completing my review paper. Secondly, I would also like to thank my friends who helped me a lot in finishing the review article within the time.

Abbreviations

USDA: The United States Department of Agriculture
POPs: Persistent Organic contaminants
PVC: Poly Vinyl Chloride
PS: Poly Styrene
BPA: Bis Phenol A
TPN: Total Parenteral Nutrition
PE: Poly Ethylene
MPs: Micro Plastic beads
PETP: Poly Ethylene Terephthalate
UNCLOS: The United Nations Convention on the Law of the Sea
NOAA: The National Oceanic and Atmospheric Association
EFSA: European Food Safety Association
INRA: National Institute of Agricultural Research

REFERENCES

Agarwala, O.P., Agarwala, C. and Amato, T. 2008. Compositions containing a nopal cactus isolate and method for making same. In : Google Patents.

Allai, L., Karym, E. M., El Amiri, B., Nasser, B., Essamad, A., Terzioðlu, P. and Öztürk, M. 2017. Evaluation of antioxidant activity and phenolic composition of Opuntia ficus-indica cladodes collected from Moroccan Settat region. *Eurasian J. Anal. Chem.* 12 : 105-117.

Andrady, A.L. and Neal, M.A. 2009. Applications and societal benefits of plastics. *Philosophical Transactions of the Royal Society B: Biological Sciences.* 364 (1526) : 1977-1984.

Andres, R., Fielding, D., Marland, G., Boden, T., Kumar, N. and Kearney, A. 1999. Carbon dioxide emissions from fossil-fuel use, 1751-1950. *Tellus B.* 51(4) : 759-765.

Atti, N., Mahouachi, M. and Rouissi, H. 2006. The effect of spineless cactus (Opuntia ficus-indica f. inermis) supplementation on growth, carcass, meat quality

and fatty acid composition of male goat kids. *Meat Science.* 73 (2) : 229-235.

Bach, C., Dauchy, X., Severin, I., Munoz, J.F., Etienne, S. and Chagnon, M.C. 2014. Effect of sunlight exposure on the release of intentionally and/or non-intentionally added substances from polyethylene terephthalate (PET) bottles into water: Chemical analysis and in vitro toxicity. *Food Chemistry.* 162 : 63-71.

Barbera, G., Inglese, P. and Pimienta-Barrios, E. 1995. *Agro-ecology, cultivation and uses of cactus pear* (Vol. 132): FAO Italy.

Baztan, J., Carrasco, A., Chouinard, O., Cleaud, M., Gabaldon, J. E., Huck, T. and Paillard, C. 2014. Protected areas in the Atlantic facing the hazards of micro-plastic pollution: First diagnosis of three islands in the Canary Current. *Marine Pollution Bulletin.* 80(1-2) : 302-311.

Bejgarn, S., MacLeod, M., Bogdal, C. and Breitholtz, M. 2015. Toxicity of leachate from weathering plastics: An exploratory screening study with Nitocra spinipes. *Chemosphere.* 132 : 114-119.

Blanco-Macías, F., Valdez-Cepeda, R. D. and Ruiz-Garduño, R. R. 2000. *Intensive production of cactus pearitos under plastic tunnels.* Paper presented at the IV International Congress on Cactus Pear and Cochineal 581.

Chisada, S., Yoshida, M. and Karita, K. 2020. Polyethylene microbeads are more critically toxic to the eyes and reproduction than the kidneys or growth in medaka, *Oryzias latipes*. *Environmental Pollution.* 115957.

Çobanoðlu, H., Belivermiþ, M., Sýkdokur, E., Kýlýç, Ö. and Çayýr, A. 2021. Genotoxic and cytotoxic effects of polyethylene microplastics on human peripheral blood lymphocytes. *Chemosphere.* 129805.

Corrales-García, J. 2007. *Industrialization of cactus pads and fruit in Mexico: Challenges and perspectives.* Paper presented at the *VI International Congress on Cactus Pear and Cochineal.* 811.

Das, O., Sarmah, A. K. and Bhattacharyya, D. 2015. A sustainable and resilient approach through biochar addition in wood polymer composites. *Science of the Total Environment.* 512 : 326-336.

Dehaan, R.L. 1971. Toxicity of tissue culture media exposed to polyvinyl chloride plastic. *Nature New Biology.* 231 (20) : 85-86.

DeMatteo, R., Keith, M.M., Brophy, J.T., Wordsworth, A., Watterson, A.E., Beck, M. and Magali, P. 2013. Chemical exposures of women workers in the plastics industry with particular reference to breast cancer and reproductive hazards. *New Solutions: A Journal of Environmental and Occupational Health Policy.* 22 (4) : 427-448.

Dev, R., Singh, J., Singh, T. and Dayal, D. 2018. Effect of shade levels on growth, and biomass production of cactus (*Opuntia ficus-india* (L.) Mill.). *Int. J. Curr. Microbiol. Appl. Sci..* 7 (1) : 3145-3153.

Dyer, R. F. and Esch, V. H. 1976. Polyvinyl chloride toxicity in fires: hydrogen chloride toxicity in fire fighters. *JAMA.* 235(4) : 393-397.

El-Samahy, S., Abd El-Hady, E., Habiba, R. and Moussa, T. 2006. Chemical and rheological characteristics of orange-yellow cactus-pear pulp from Egypt. *Journal of the Professional Association for Cactus Development.* 8 : 39-51.

Endo, K. 2002. Synthesis and structure of poly (vinyl chloride). *Progress in Polymer Science.* 27(10) : 2021-2054.

Feldman, D. and Barbalata, A. 1996. *Synthetic Polymers: Technology, Properties, Applications*: Springer Science and Business Media.

Gao, M., Liu, Y. and Song, Z. 2019. Effects of polyethylene microplastic on the phytotoxicity of di-n-butyl phthalate in lettuce (*Lactuca sativa* L. var. ramosa Hort). *Chemosphere.* 237 : 124482.

Gebremariam, T., Melaku, S. and Yami, A. 2006. Effect of different levels of cactus (*Opuntia ficus-indica*) inclusion on feed intake, digestibility and body weight gain in tef (Eragrostis tef) straw-based feeding of sheep. *Animal Feed Science and Technology.* 131(1-2) : 43-52.

Gewert, B., Plassmann, M. M. and MacLeod, M. 2015. Pathways for degradation of plastic polymers floating in the marine environment. *Environmental Science: Processes and Impacts.* 17(9) : 1513-1521.

Geyer, R. 2020. Production, use, and fate of synthetic polymers. In: *Plastic Waste and Recycling* (pp. 13-32): Elsevier.

Godswill, A.C. and Godspel, A.C. 2019. Physiological Effects of Plastic Wastes on the Endocrine System (Bisphenol A, Phthalates, Bisphenol S, PBDEs, TBBPA). *International Journal of Bioinformatics and Computational Biology.* 4 (2) : 11-29.

Goldman, G., Vinokur, Y., Horev, B., Lurie, S., Rodov, V. and Liguori, G. 2004. *Fresh-cut products from cactus species.* Paper presented at the *V International Postharvest Symposium,* 682.

Grigore, M. 2017. Methods of recycling, properties and applications of recycled thermoplastic polymers. *Recycling.* 2(4) : 24.

Groh, K. J., Backhaus, T., Carney-Almroth, B., Geueke, B., Inostroza, P. A., Lennquist, A. and Trasande, L. 2019. Overview of known plastic packaging-associated chemicals and their hazards. *Science of the Total Environment.* 651 : 3253-3268.

Guillet, J., Huber, H. and Scott, J. 1992. Biodegradable polymers and plastics. In: The Royal Society of Chemistry, Cambridge.

Hahladakis, J. N., Velis, C. A., Weber, R., Iacovidou, E. and Purnell, P. 2018. An overview of chemical additives present in plastics: migration, release, fate and environmental impact during their use, disposal

and recycling. *Journal of Hazardous Materials.* 344: 179-199.

Heindler, F. M., Alajmi, F., Huerlimann, R., Zeng, C., Newman, S. J., Vamvounis, G. and van Herwerden, L. 2017. Toxic effects of polyethylene terephthalate microparticles and Di (2-ethylhexyl) phthalate on the calanoid copepod, Parvocalanus crassirostris. *Ecotoxicology and Environmental Safety.* 141: 298-305.

Ignatyev, I. A., Thielemans, W. and Vander Beke, B. 014. Recycling of polymers: a review. *Chem Sus Chem.* 7 (6) : 1579-1593.

Joseph, N., Kumar, A., Majgi, S. M., Kumar, G. S. and Prahalad, R.B.Y. 2016. Usage of plastic bags and health hazards: A study to assess awareness level and perception about legislation among a small population of Mangalore city. *Journal of Clinical and Diagnostic Research: JCDR.* 10(4) : LM01.

Kang, J. H., Kondo, F. and Katayama, Y. 2006. Human exposure to bisphenol A. *Toxicology.* 226(2-3) : 79-89.

Koch, H.M. and Calafat, A.M. 2009. Human body burdens of chemicals used in plastic manufacture. *Philosophical Transactions of the Royal Society B: Biological Sciences.* 364(1526) : 2063-2078.

Koshti, R., Mehta, L. and Samarth, N. 2018. Biological recycling of polyethylene terephthalate: A mini-review. *Journal of Polymers and the Environment.* 26 (8) : 3520-3529.

Kumar, P. 2020. Designing zero plastic policy and its implementation: major role of Law to protect environment, Plastic everywhere. *National Journal of Environmental Law.* 2 (2).

Kumar, R. V., Kanna, G. and Elumalai, S. 2017. Biodegradation of polyethylene by green photosynthetic microalgae. *J Bioremediat Biodegrad.* 8 (381) : 2.

LI, W. C., Tse, H. and Fok, L. 2016. Plastic waste in the marine environment: A review of sources, occurrence and effects. *Science of the Total Environment.* 566 : 333-349.

Lithner, D., Larsson, Å. and Dave, G. 2011. Environmental and health hazard ranking and assessment of plastic polymers based on chemical composition. *Science of the Total Environment.* 409 (18) : 3309-3324.

Lithner, D., Nordensvan, I. and Dave, G. 2012. Comparative acute toxicity of leachates from plastic products made of polypropylene, polyethylene, PVC, acrylonitrile–butadiene–styrene, and epoxy to Daphnia magna. *Environmental Science and Pollution Research.* 19(5): 1763-1772.

Loff, S., Kabs, F., Witt, K., Sartoris, J., Mandl, B., Niessen, K. and Waag, K. 2000. Polyvinylchloride infusion lines expose infants to large amounts of toxic plasticizers. *Journal of Pediatric Surgery.* 35 (12) : 1775-1781.

Mak, C.W., Yeung, K.C.F. and Chan, K.M. 2019. Acute toxic effects of polyethylene microplastic on adult zebrafish. *Ecotoxicology and Environmental Safety.* 182 : 109442.

Mangaraj, S., Yadav, A., Bal, L.M., Dash, S. and Mahanti, N.K. 2019. Application of biodegradable polymers in food packaging industry: a comprehensive review. *Journal of Packaging Technology and Research.* 3(1) : 77-96.

Maraveas, C. 2020. Production of sustainable and biodegradable polymers from agricultural waste. *Polymers.* 12(5) : 1127.

Mayer, J. A. and Cushman, J. C. 2019. Nutritional and mineral content of prickly pear cactus: A highly water-use efficient forage, fodder and food species. *Journal of Agronomy and Crop Science.* 205(6) : 625-634.

Mulder, K.F. 1998. Sustainable consumption and production of plastics? *Technological Forecasting and Social Change.* 58 (1-2) : 105-124.

Nharingo, T., Zivurawa, M. and Guyo, U. 2015. Exploring the use of cactus *Opuntia ficus* indica in the biocoagulation-flocculation of Pb (II) ions from wastewaters. *International Journal of Environmental Science and Technology.* 12(12) : 3791-3802.

Nolen, Z. J., Allen, P. E. and Miller, C. W. 2017. Seasonal resource value and male size influence male aggressive interactions in the leaf footed cactus bug, Narnia femorata. *Behavioural Processes.* 138: 1-6.

Otake, Y., Kobayashi, T., Asabe, H., Murakami, N. and Ono, K. 1995. Biodegradation of low-density polyethylene, polystyrene, polyvinyl chloride, and urea formaldehyde resin buried under soil for over 32 years. *Journal of Applied Polymer Science.* 56(13) : 1789-1796.

Parolini, M., De Felice, B., Gazzotti, S., Annunziata, L., Sugni, M., Bacchetta, R. and Ortenzi, M. A. 2020. Oxidative stress-related effects induced by micronized polyethylene terephthalate microparticles in the Manila clam. *Journal of Toxicology and Environmental Health, Part A.* 83(4): 168-179.

Pilevar, Z., Bahrami, A., Beikzadeh, S., Hosseini, H. and Jafari, S.M. 2019. Migration of styrene monomer from polystyrene packaging materials into foods: Characterization and safety evaluation. *Trends in Food Science and Technology.* 91 : 248-261.

Pimienta-Barrios, E. 1994. Prickly pear (Opuntia spp.): a valuable fruit crop for the semi-arid lands of Mexico. *Journal of Arid Environments.* 28(1) : 1-11.

Pittura, L., Avio, C. G., Giuliani, M. E., d'Errico, G., Keiter, S. H., Cormier, B. and Regoli, F. 2018. Microplastics as vehicles of environmental PAHs to marine organisms: combined chemical and physical hazards to the Mediterranean mussels, Mytilus galloprovincialis. *Frontiers in Marine Science.* 5 : 103.

Pritchard, G. 2012. *Plastics Additives: an AZ Reference* (Vol. 1): Springer Science and Business Media.

Rodriguez-Felix, A. 2000. *Postharvest physiology and technology of cactus pear fruits and cactus leaves.* Paper presented at the *IV International Congress on Cactus Pear and Cochineal,* 581.

Salem, H. B., Nefzaoui, A. and Salem, L. B. 2002. Supplementing spineless cactus (*Opuntia ficus-indica* f. inermis) based diets with urea-treated straw or oldman saltbush (*Atriplex nummularia*). Effects on intake, digestion and sheep growth. *The Journal of Agricultural Science.* 138 (1) : 85.

Sati, P.C., Khaliq, F., Vaney, N., Ahmed, T., Tripathi, A.K. and Banerjee, B.D. 2011. Pulmonary function and oxidative stress in workers exposed to styrene in plastic factory: occupational hazards in styrene-exposed plastic factory workers. *Human & Experimental Toxicology.* 30(11) : 1743-1750.

Scarascia-Mugnozza, G., Sica, C. and Russo, G. 2011. Plastic materials in European agriculture: actual use and perspectives. *Journal of Agricultural Engineering.* 42(3) : 15-28.

Silva, E. T. d. S., Melo, A. A. S. d., Ferreira, M. d. A., Oliveira, J. C.V.D., Santos, D. C. D., Silva, R. C. and Inácio, J. G. 2017. Acceptability by Girolando heifers and nutritional value of erect prickly pear stored for different periods. *Pesquisa Agropecuária Brasileira.* 52(9) : 761-767.

Thakur, S., Verma, A., Sharma, B., Chaudhary, J., Tamulevicius, S. and Thakur, V.K. 2018. Recent developments in recycling of polystyrene based plastics. *Current Opinion in Green and Sustainable Chemistry.* 13: 32-38.

Verleye, G.A., Roeges, N.P. and De Moor, M.O. 2001. *Easy Identification of Plastics and Rubbers*: iSmithers Rapra Publishing.

Vince, J. and Hardesty, B.D. 2018. Governance solutions to the tragedy of the commons that marine plastics have become. *Frontiers in Marine Science.* 5 : 214.

Vogel, S.A. 2009. The politics of plastics: the making and unmaking of bisphenol a "safety". *American Journal of Public Health.* 99 (S3) : S559-S566.

Xanthos, D. and Walker, T. R. 2017. International policies to reduce plastic marine pollution from single-use plastics (plastic bags and microbeads): a review. *Marine Pollution Bulletin.* 118 (1-2) : 17-26.