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Chapter 4

White Pollution:
A Hazard to Environment and Sustainable Approach to Its Management

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ABSTRACT

Plastic derived from the petrochemical industry with a high molecular weight constitutes about 9-13% of total solid waste. Since the industrial revolution, the use of plastic has increased manifold without improving its adequate management as a waste. Most of the plastic waste produced in the world is mainly from packaging industry followed by building and construction. Plastic is a non-degradable deadly pollutant to degrade environmental quality and are known to remain in water and soil for years without making any change in their structure. Due to enormous generation, open burning of plastic is also preferred due to the lack of resource in the developing countries thus releasing toxic gases thereby causing air pollution. Plastic disturbs the balance of the environment by acting as physical barrier leading to the drainage of the drains, degrading soil properties, and are often ingested by the organisms ultimately leading to their death. Thus, it becomes more important to manage the plastic pollution keeping in view its detrimental impacts on the environment.

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INTRODUCTION

Population explosion as well as urbanization leads to the enormous quantity of waste generation (Camill, 2010; Bhat et al., 2014; Bhat et al., 2018) and this waste generated is known as municipal solid waste (Kumar et al., 2016). The availability of the different alternative choices of the product has resulted in the short life span of the single product. Apart from that, the new trend is the use of disposable products which are produced, used and disposed easily (Ahmed and Ali, 2004). The generation of waste is directly related to the economic background (Bhat et al., 2012) as the economically sound families produce more quantity of the waste compared to poor families (Ambulkar & Shekdar, 2004). The waste is generated in such a large quantity if it is allowed to be disposed of in landfill than whole earth will soon get covered with waste (Buenrostro & Bocco, 2003) and if the waste is treated by incineration, toxic pollutant are released which will ultimately destroy the climate of the earth (Kumar et al., 2009). Plastic waste constitutes the major proportion of the solid waste (Sangawar & Deshmukh, 2012) thus it became important to look for good management techniques like recycling which help to minimize the quantity of the waste (Zmak & Hartmann, 2017).

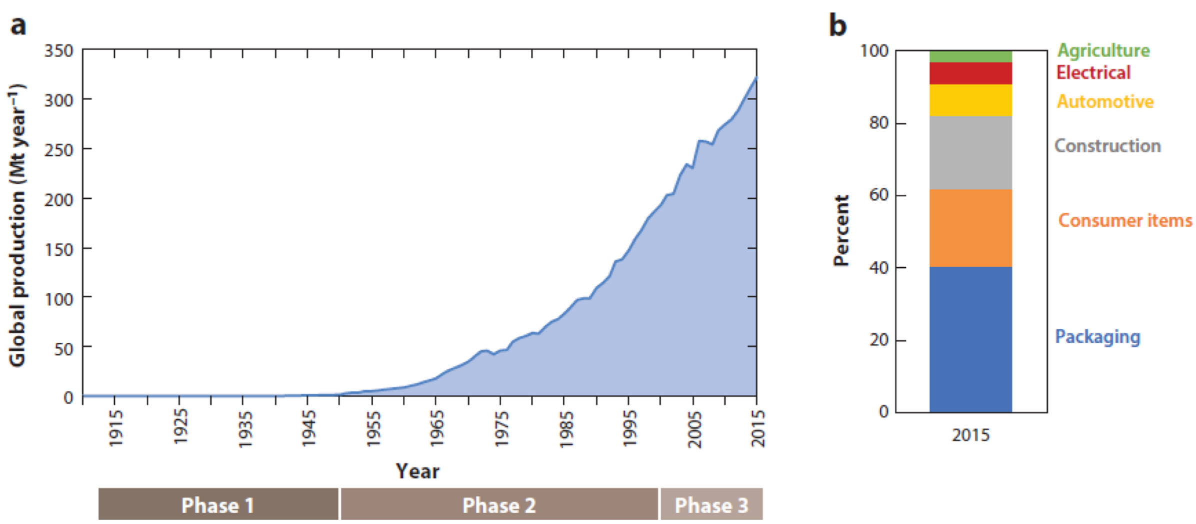
The word 'plastic' comes from the Greek word 'plasticos', which means on heating, changes the shape and form a totally different product. Plastic invented a century ago (Baekeland, 1909) is one of the widely used human made product and can be found in every nook and corner of the country. Plastic has found its use in every field of the life and each person on an average produce 52 kg of plastic waste annually (Jambeck et al., 2015). Geologists are now considering a plastic horizon in the world's soils and sediments as one of the key indicators marking the current geological epoch, the anthropocene (Waterset al., 2016). 'Polymers' the generic term for all kinds of plastic materials, produced mostly from the petro industry is a giant molecule of the carbon-based organic compounds (Ismail & Hashmi, 2008). The use of polymers in alloys and blends has increased its uses for the production of different kinds of products as blending of polymers increase performance as well as life of the product (Gupta et al., 1998). Plastics waste is mainly produced from the packaging of the material, daily use as carry bags and discarded items (Staniskis, 2005). Plastic are having extensive industrial applications (Heskett et al., 2012) because of their cheapness, strength, durability and many other properties which make them one of the most commonly used products on the earth (Andrady, 2011). The single largest consumer is the packaging industry which uses more than 1/3rd of the plastic (Schmidt et al., 2017). The good quantity (0.2- 0.3%) of the plastic waste ultimately reach to the oceans thereby leads to the degradation of the ocean ecosystem (Andrady & Neal, 2009). The products produced from plastic are the major part of human life and due to their increased use, the production on global level has reached more than 150 million tonnes annually (Rillig, 2012). The comparison of per capita plastic consumption with the rest of the word is presented in Table 1.

Further, as per the data from World Economic Forum, the quantity of waste and green house gases generation increases with the production and consumption of the plastic (Wohlleben & Neubauer, 2016)

Table 1. Plastic waste consumption

S.N.	Country/Continent	Per Capita/Year Consumption (Kg)
1	India	6.0
2	East Europe	10.0
3	South East Asia	10.0
4	China	24.0
5	West Europe	65.0
6	North America	90.0
7	World Average	25.0

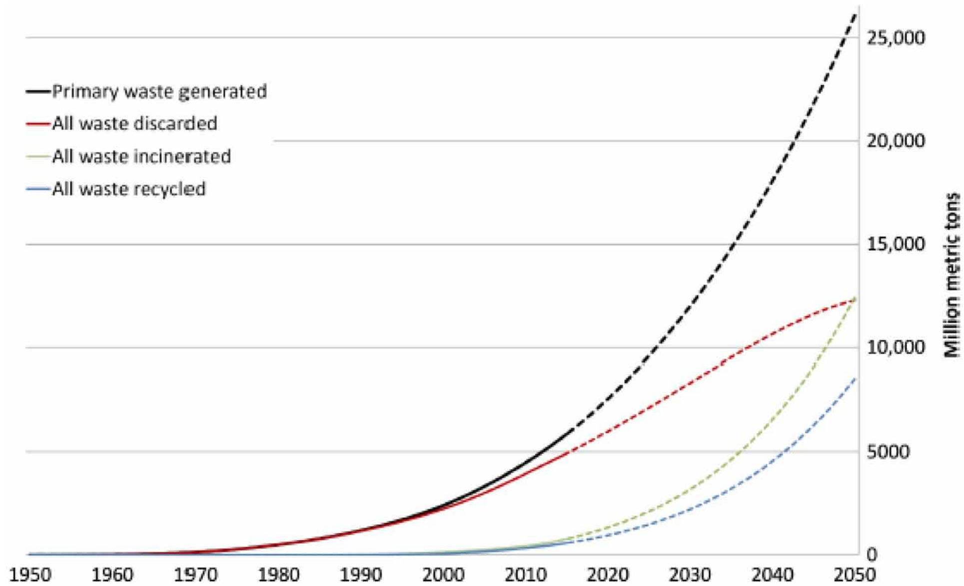
Figure 1. "Time trends in total plastics production worldwide. (a) Global production in million metric tons per year (Mt year^{-1}). (b) Usage patterns of plastic in 2016 are estimated from available sources (Plastics Europe, 2016). Three phases are seen: Phase 1 signifies slow development and invention of most plastics commonly used today (innovation phase), Phase 2 is marked by rapid global expansion and exponential growth (growth phase), and Phase 3 shows more linear dynamics that more closely mirrors global economic growth (consolidation phase)"(Plastics Europe, 2016; Plastics Europe, 2012; ACS, 1993)



PLASTIC AND HEALTH IMPLICATIONS

The use, recycling or keeping of plastic untouched in the environment results in the breakdown (Barnes et al., 2009) and release of heavy metals (cadmium and lead) and other harmful chemicals like benzene, dioxins which are the serious environmental pollutants (Wagner & Oehlmann, 2009). The chemicals use to enhance the properties of the plastic are released back into the environment making it more harmful to the health of living organisms (Kakuta, 2008). The large quantity of the synthetic chemicals are (>82,000) are available for use but most of them are untested and from the tested one, few chemical

Figure 2. "Cumulative plastic waste generation and disposal (in million metric tons)". Solid lines show historical data from 1950 to 2015; dashed lines show projections of historical trends to 2050" (Geyer et al., 2017)



are totally banned for manufacturing (Landrigan et al., 2002). BPA and phthalates having different uses can easily leach to the food chain and can directly affect human health (Adibi, et al., 2003; Anastas & Beach, 2007). The leaching of these chemicals increases with the age of the plastic and also due to contact with fatty food on heating (Mato et al., 2001). The burning of plastics releases various harmful gases like carbon monoxide gas (CO) and carbon dioxide (CO_2) which have serious impact on the human health (Moore, 2008). During the incineration of PVC, colorless gas and strong poisonous gas called 'Phosgene' is produced having serious effects on human health (Waters et al., 2016). The combustion of the plastic waste also results in the release of ashes and soot which ultimately settle on the plants or on the surface of water bodies or on the ground surface thereby effecting the almost all the component of the environment (Waggoner, 2006). The functioning of the aquatic ecosystem is disturbed as some of the pollutant released react directly with the water and results in the change in pH of the system (Mato et al., 2001). The compounds generated by the incineration of PVC and its harmful health effects are presented in the following Table 2

PLASTIC IN OCEANS

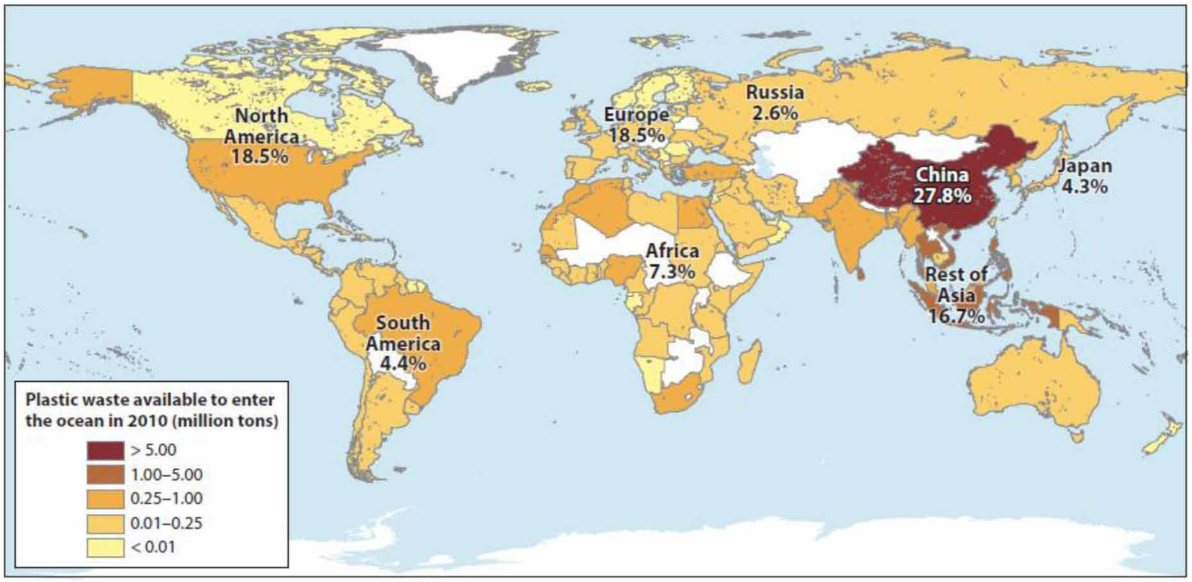
The improper management of the waste has resulted in the accumulation of the plastic waste in the oceans. The major quantity of the waste accumulated in the ocean is the plastic followed by metals, glass and paper (Galgani et al., 2010). The accumulation of the plastic waste in ocean is considered global problem by United Nations Environment Assembly (Gesamp, 2016; Werner et al., 2016). The largest sector consuming plastic in Europe currently (Plastics Europe, 2016) is single-use packaging (40%), followed by consumer goods (22%) construction materials (20%) and automotive (9%), electrical (6%),

Table 2. Generated compounds and their harmful effects during the incineration of PVC (Pal, 1990)

Name of Compound	Health Effects
‘Acetaldehyde”	“It damages the nervous system, causing lesions”
“Acetone”	“Irritates the eyes, the respiratory tract”
“Benzaldehyde”	“Irritates the eyes, skin, respiratory system, limits brain function”
“Benzole”	“Carcinogenic, adversely affects the bone marrow, the liver, the immune system”
“Formaldehyde”	“Serious eye damage, carcinogenic, may cause pulmonary oedema”
“Phosgene”	“The gas used in the WWI. Corrosive to the eyes, skin and respiratory organs”
“Polychlorinated dibenzo-dioxin”	“Carcinogenicirritate the skin, eyes and respiratory system. It damages the circulatory, digestive and nervous system, liver, bone marrow”
“Polychlorinated Dibenzofuran”	“Irritates the eyes and the respiratory system, causes asthma”
“Hydrochloric acid”	“Corrosive to the eyes, the skin and the respiratory tract”
“Salicyl-aldehyde”	“Irritates the eyes, the skin, and the respiratory tract. It can also affect the central nervous system”
“Toluene”	“Irritates the eyes and the respiratory tract, can cause depression”
“Xylene”	“Irritates the eyes. It can also affect the central nervous system, reduces the level of consciousness and impairs learning ability”
“Propylene”	“Damages the central nervous system by lowering of consciousness”
“Vinyl chloride”	“Carcinogenic, irritating to eyes, skin and respiratory system. Effect on the central nervous system, liver, spleen, blood-forming organs”

and agriculture applications (3%). The continuous rise in the use of plastic is a serious issue as use of plastic is expected to grow 4% annually (Plastics Europe, 2016). The annual production of the plastic in the world is comparable to the average weight (45 Kg) of the human population on the earth. Almost half (49%) of the plastic production was done in Asia with China being the world’s largest producer (28%), followed by Europe and North America, each contributing 19% (Figure 3). The non-degradable nature and improper management of the plastic has resulted in the entering into the ocean from land-based sources, often via rivers, wastewater outflows, and transport by wind or tides (Jambeck et al., 2015). The constant increase in plastic production followed by a continuous supply of waste in oceans is expected to continue the long-term accumulation of plastic in marine ecosystems. In 2010, the amount of plastic waste (4.8-12.7 Mt) (Jambeck et al., 2015), released into the marine environment is estimated to be equal to the dumping of garbage truck of plastic every minute (Newscentre, 2017). The difference in the accumulation of plastic in different countries is dependent on several factors like coastal population density, quantity of plastic produced annually and management practices. The major proportion of the waste in the ocean comes from the coastline of China and United States (Jambeck et al., 2015). The enormous quantity of waste generated is not managed properly as in individual countries about 2-90% of the waste is mismanaged and 2-25% of mismanagement of waste is contributed by plastic (Jambeck et al., 2015). In India and US, coastal areas of the both countries is covered by almost same population (188 and 113 million people) and generation of waste per person is more in US compared to India but

Figure 3. "Spatial patterns of plastic production and pollution. Shown are the percentage contributions of different regions to global plastic production and the estimated mass of mismanaged plastic waste in million tons (Mt) generated in 2010 by populations living within 50 km of the coast" (Jambeck et al., 2015)



mismanagement of the waste is more in India (88%) compared to US (2%). Due to the improper management of the waste, India contributes more in the marine plastic pollution compared to US (Jambeck et al., 2015). The majority of the marine plastic pollution (44%) is contributed by three countries namely China, Indonesia and the Philippines as coastal areas are mostly inhibited by peoples, rapidly increasing consumption of plastics and following poor waste management practices. Jambeck et al., (2015) predicted a three-fold increase in the number of plastics in the ocean between 2015 and 2025 (Figure 4).

EFFECTS OF MICROPLASTICS AND NANO-PLASTIC ON MARINE ORGANISMS

Microplastic has large surface area and has capability to cross cellular boundaries thereby effecting the various functioning within the body of the living organisms (Gesamp, 2016). The entering of the microplastic in the body effects the growth and development as it directly effects feeding habits and reproduction ability of the organism. Scientists have predicted that microplastic may alter the functioning by effecting the growth and development of the organisms (Jambeck et al., 2015). Some animals have capacity to carry out carry carbon to the different ocean depths but increasing plastic accumulation can have impact on such capability of the organism thus effects the balance of the marine ecosystem (Thompson et al., 2009).

"Nanoplastics" are the fragment of the plastic having dimension smaller than 100 nm and can be present in marine water as single particles or aggregates of particles. The impact of nanoplastic on the health of different organism is very scarce and need more extensive research to know about the impact

Figure 4. "The estimated mass of plastic waste that enters the ocean because of inadequate waste management from populations living within 50 km of coast in 192 countries, plotted as a cumulative sum from 2010 to 2025. Estimates reflect assumed conversion rates of mismanaged plastic waste to marine debris (high, 40 percent; mid, 25 percent; low, 15 percent)" (Jambeck et al., 2015)

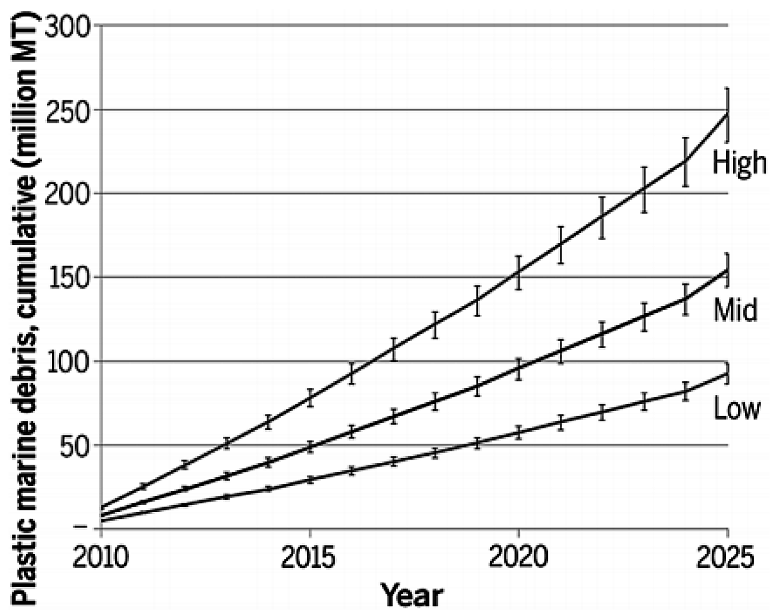
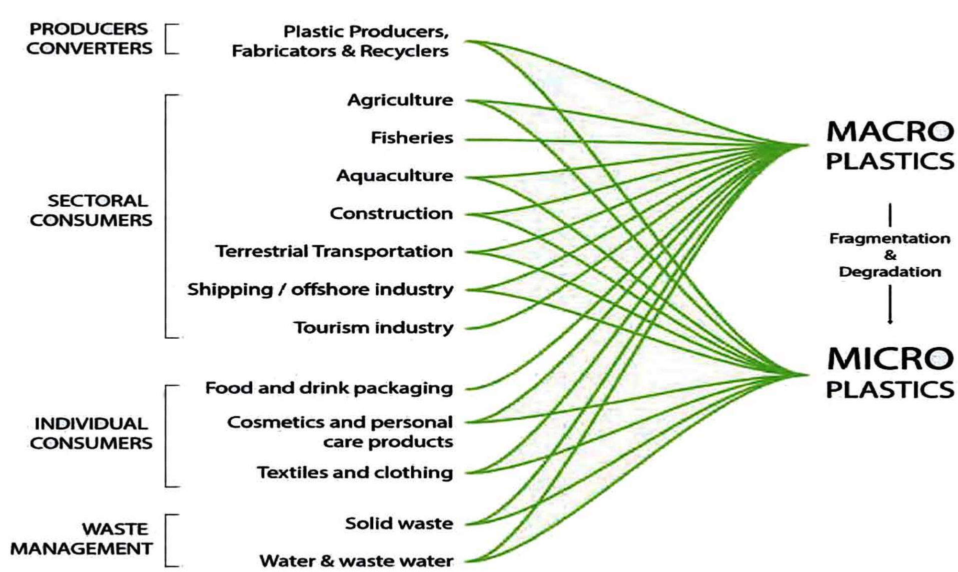


Figure 5. "Potential sources of microplastics to the marine environment" (Gesamp, 2016)



on the various bodies functioning of the organisms (Canesi et al., 2015). As per laboratory experiment, nanoparticles caused behavioral disorder as nanoplastic were able to pass from algae to zooplankton and then to fish in the food web (Mattson et al., 2017). During whole lifetime, animals are exposed to nanoplastic although in very small amount and are known to show synergistic effect (Canesi et al., 2015) with different toxins like chromium toxicity in fish increased in the presence of microplastic (Luıs et al., 2015).

PLASTICS AND THE ENVIRONMENT

Impact of plastic pollution on the environment is now recognized global issue (Meeker et al., 2009; Oehlmann et al., 2009). The problem of plastic pollution is rising as almost 4/5th of the waste which accumulates is the plastic waste (Barnes et al., 2009). The different properties and uses like in paints, cable covering (Andrady & Neal, 2009; Koch & Calafat, 2009; Meeker et al., 2009; Oehlmann et al., 2009; Talsness et al., 2009; Wagner & Oehlmann 2009) has made plastic as one of the important part of human life but pose serious threats after use to living organisms as well as to their environment (Thompson et al., 2009). Plastic being cheap and easily available has numerous uses like in food industry can be used to pack different kinds of products which has significantly increased the quantity of the plastic waste production (ECOSS, 2014). The increased use of the plastic bags has made them one of the toxic pollutants in recent decades as plastic are made up of toxic chemicals which results in the pollution of air, water and soil (ECOSS, 2014). The chemicals used for the production has serious impact as some of them are carcinogenic ("benzene and vinyl chloride") while the gases ("ethylene oxide, benzene, and xylenes") (Swan et al., 2005; Swan 2008) released on the combustion of the plastic are responsible for the degradation of the environment (Rudel et al., 2001,2003; Oehlmann et al., 2009).The multiple uses of the plastic has resulted in the enormous production of the plastic waste which often get mixed with the general waste and cause problems in the management of the waste (UNEP, 2009; Kaewlue et al., 2012). Plastic known for its stability and durability (ECOSS, 2014) does not undergo degradation and disposing to landfill sites means allowing toxic pollutants to accumulate forever (UNEP, 2009; Kaewlue et al., 2012) in the water and soil of the surrounding area.

The rate of degradation of the plastic is very slow and took years to degrade in favorable conditions (Massardier-Nageotte et al., 2006) like high humidity and high oxygen supply (Allen et al., 1988). The plastic bottles can persist in the wet soil between 35-180 years as plastic bottle loses viscosity with time and finally disintegrate into micro-plastic (Allen et al., 1994; Edge et al., 1991). In marine environment, the degradation of the plastic starts in few weeks (Kedzierski et al., 2018) but took few decades or centuries or more for total degradation of the plastic waste due to presence of low temperature, low oxygen concentration and absence of sunlight (Barnes et al., 2009; Ioakeimidis et al., 2016). The materials like wood or pollen have high degradation rate but can be preserved for numerous years under such conditions (Blanchette et al., 1991; Boswijk et al., 2006; Haberle & Maslin, 1999).

ENVIRONMENTAL IMPACTS

Marine environment contaminated with plastic affects the flora and fauna of the marine ecosystem (Werner et al., 2016). Plastic accumulation in the marine ecosystem results in physical damage to the various organisms as direct ingestion of the plastic by various organism like turtle by mistake as food source (Derraik, 2002). The fragile marine ecosystem is also disturbed by the continuous accumulation of the plastic waste at the bottom and removal of debris certainly disturbs the balance of the marine ecosystem (Goldberg, 1994; Kanehiro et al., 1995). Human are also indirectly affected as ingestion of plastic by marine organism will get accumulated in the human body feeding on marine organisms for food (Mato et al., 2001). The persistent nature of the plastic demands strong steps for management of the plastic waste otherwise the frequency of the impact will increase manifolds. Thus, it is important not to disturb the balance of marine ecosystem so that the various species can be conserved, and the only available solution is to shun the production as well as use of plastic (Kanehiro et al., 1995).

Impacts on Marine Wildlife

The increase in the development in science has resulted in the production of the product which has many benefits for the human population but the impacts on the environment are not taken into consideration (Holmes et al., 2012). With the increase of the population, the use of the plastic is also increasing but absence of the management practice has led to the accumulation of the plastic in marine ecosystem (Browne et al., 2015). The accumulation of the plastic by the birds has increased with the quantity of the waste accumulation in the marine ecosystem. The marine plastic debris is affecting the number of species (267 species) throughout the world including 86% of all sea turtle species, 44% of all seabird species and 43% of all marine mammal species (Derraik, 2002). Seabed debris consists of plastic (80–85%) that are buoyant and buoyant debris can inhibit the gas exchange process between bottom and top surface of the marine ecosystem thus results in the creation of the hypoxia or anoxia condition (Goldberg, 1994; Kanehiro et al., 1995).The impact varies with the size and type of the debris and also varies with the different levels of organization in different habitat (Browne et al., 2015; UNEP, 2016; Werner et al., 2016). The ingestion of the plastic by various species of the marine environment increases if the size of the particle is in the range of < 5mm. As per studies conducted in laboratory, microplastic can easily transfer from prey to the predator (Watts et al., 2015) and can also facilitate in the transfer of toxic chemicals (Holmes et al., 2012; Rochman & Browne, 2013; Rochman et al., 2013).

Impacts on Sea Turtles

Almost all the species of sea turtle are prone to plastic pollution in the marine environment as turtle are harmed by feeding on plastic. Sea turtle feed mainly on jelly fish but floating plastic bags seem them like jellyfish and feeding on plastic bags results in the accumulation of plastic in their body (Mrosovsky et al., 2009). Sublethal impacts of plastics on sea turtles can be substantial, yet mortality resulting from interactions with plastic is much more difficult to quantify.

Ingestion of Plastic

The different organisms like seabirds, sea turtles, fish and mammals living in the marine environment ingest plastic by mistake for food (Thompson et al., 2009). For example, whales and sea turtles habitually mistake plastic bags for squid and birds usually mistake plastic pellets for fish eggs (Lee et al., 2001; Moore, 2002). A study conducted on 38 green turtles found that more than half (61%) of the turtles swallowed the accumulated debris like plastic bags, cloth and rope (Bugoni et al., 2001). Another study conducted in USA observed that 568 out of 1033 species were found to have plastic material in their body (Moser & Lee, 1992). The marine plastic debris contain some chemical (Moore, 2002) which can cause reproductive failure and even result in the death of the organism. The plastic material in the body of seabird is directly due to their scavenging strategies and diet (Azzarello &Van-Vleet, 1987; Ryan, 1987a; Moser & Lee, 1992; Laist, 1997). Plastic debris ingested by the marine organisms can be the way for entrance of PCBs into the food chain (Carpenter & Smith, 1972; Carpenter et al., 1972; Rothstein, 1973; Zitko & Hanlon, 1991; Mato et al., 2001) and even in low concentration can poses a serious risk to the life of different organisms by changing the level of hormones in the body or directly attacking reproductive organs (Ryan et al., 1988; Lee et al., 2001).

INDIRECT ENVIRONMENTAL IMPACTS

The impact is not restricted to animal only, but plants and other immobile organism are also affected to great extent by plastic debris (Zitko & Hanlon, 1991; Mato et al., 2001). Coral reefs are typically spoiled by dilapidated fishing equipment that breaks or suffocates coral. Plants can be smothered by plastic bags and fishing nets. The ocean floor ecosystems can be damaged and altered by the movement of an abandoned vessel or other marine debris (Lee et al., 2001).

Ecosystem Alteration

The removing of the plastic debris from the bottom of the marine ecosystem by using tractor can disturb the balance of marine flora and fauna. This technique of removal is usually unsafe for aquatic flora, birds, sea turtles, and other marine organisms. Erosion of shore-line and disruption of natural vegetation is a serious consequence of beach raking when conducted too close to a dune (Laist, 1997; Moser & Lee, 1992)

Invasive Species

Plastic debris from the marine environment can result in the transfer of the invasive species. The floating plastic debris carries dangerous species from one location to the other and result in the spreading of dangerous species (Barnes, 2002). In 2002, a study conducted by British Antarctic Survey estimated that due to the increased accumulation of the plastic waste in the marine environment, the number of the species doubled in the subtropics (Barnes, 2002).

Economic Impacts

The main important component of our economy is directly affected by the plastic pollution in the marine environment. The main components are tourism, fishing and navigation.

Tourism

The impacts of plastic pollution in marine environment are loss of key species, decrease the quality of the water, fish population decreases, foul smell from the water and create problems in navigation (Figure 7) thereby results in the less tourist influx in the area (Browne et al., 2015; UNEP, 2016; Werner et al., 2016). However, evaluating individual socio-economic costs of litter is challenging because of limited understanding about impacts and as a consequence of the variety of approaches that can be used to place economic values on the natural environment. The cost of removing debris from the marine ecosystem is laborious, time consuming, costly and also poses risk to the survival of the marine organisms (UNEP, 2016; Werner et al., 2016). The enormous accumulation of the plastic waste results in foul smell and even sometime cause beach closure which is ultimately affecting the number of tourist coming in the area (Barnes, 2002).

Fishing

The most commonly affected due to plastic debris is the fisheries (Rothstein, 1973; Zitko & Hanlon, 1991; Mato et al., 2001). The enormous quantity of the waste accumulated prevents the movement of the fish as fishes may get trapped in the polythene bags (Mato et al., 2001). The chemical released in the marine environment by the plastic waste affect the reproductive potential and also cause feminizing in the fish. The vessels and fishing gear get damaged by the marine debris which leads to extra cost on the repairing and wastage of the days of fisherman without any output in the business (Werner et al., 2016)

Navigation

Floating marine debris is a navigational hazard that entangles propellers and clogs cooling water intake valves (Reinhard et al., 2012). A survey by Scottish trawlers obtained the data on most common material that get trapped in the fishing gear are ropes and plastic (Figures 5 and 6). The floating debris also prevents the smooth movement of the water boats thus consume time as well as fuel thereby adding extra financial burden on the boatmen (Browne et al., 2015; UNEP, 2016; Werner et al., 2016). Sometimes boats are also damaged by the marine debris and repairing of boats is expensive as well as time consuming. Repairing boats damaged by marine debris is both time-consuming and expensive. The impacts related to marine debris is going to increase with time as the management of the plastic waste is lacking the effective techniques necessary to deal the enormous quantity of plastic waste generation (Reinhard et al., 2012).

Figure 6. Impacts of the beach and marine litter on socio-economic activities (Reinhard et al., 2012)

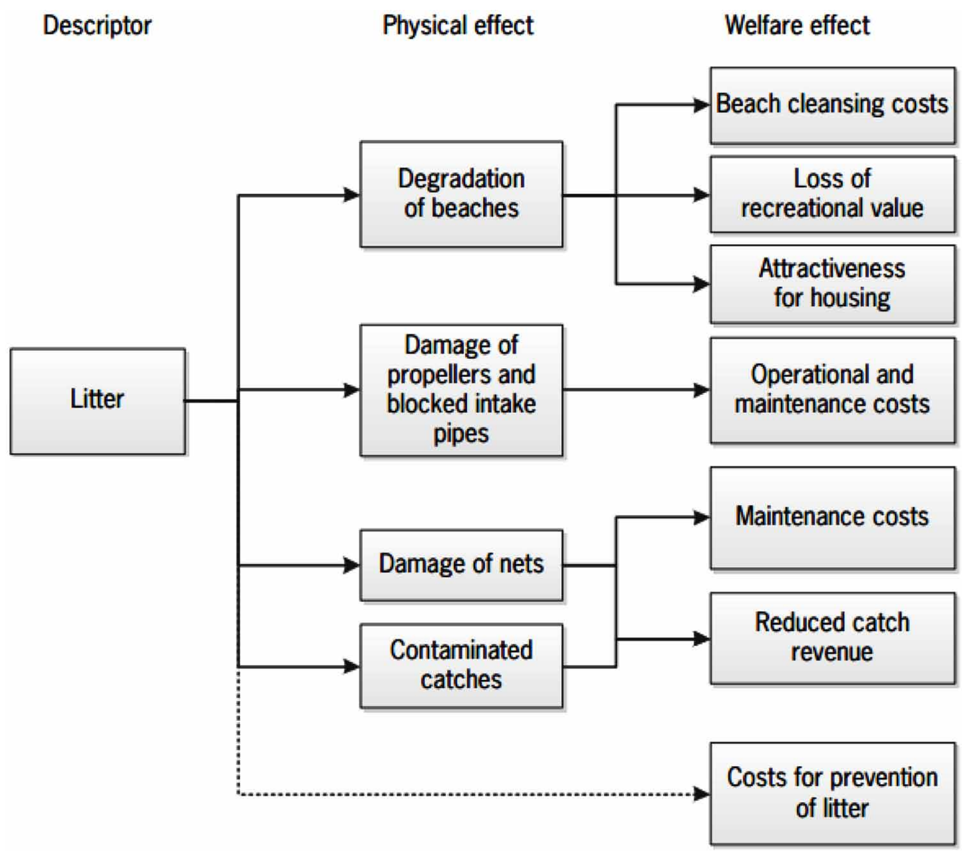
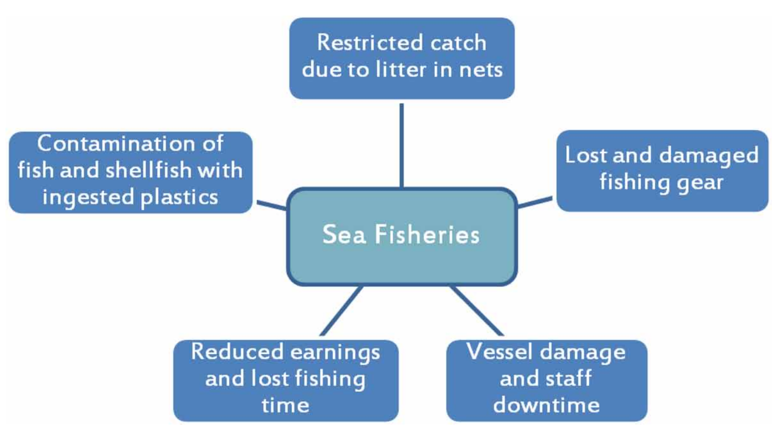


Figure 7. Potential impacts of marine litter on fisheries (Mouat et al., 2010)



DISPOSAL AND WASTE MANAGEMENT SOLUTIONS

The consequences related to the plastic debris in marine environment are numerous but avoidable. The accumulation of plastic waste in marine environment can be prevented by improving the management techniques (WRAP, 2006, 2008; Defra, 2007). Disposal of plastic waste in improper manner has also increased with the use of disposal material. The plastic waste can also be managed by using the concept of 3 R's (Reduce, Reuse, Recycle) in order to reduce the enormous quantity of the waste generated (Hopewell et al., 2009). Energy recovery and molecular redesign are the emerging strategy for the management of the plastic waste hence instead of 3R's, 5R's (Reduce, Reuse, Recycle, Recover and Redesign) strategy can play efficient role in the management of the increasing plastic waste.

The life cycle analysis calculated that using recycled PET can help to reduce the emission of carbon dioxide by 27% compared to the use of virgin PET (WRAP, 2006, 2008; Defra, 2007). Recycling is easy for the products made up of single polymer compared to products made up of composite items. Public awareness and support is necessary to achieve good recycling targets as in some countries like in America and UK, public support for recycling is 80% and 57% respectively (Hopewell et al., 2009). The awareness and support for the recycling of the plastic waste is lacking in developing countries which results in the accumulation of plastic waste in almost every ecosystem.

Degradable Polymers

The hazard associated with the use of plastic has forced to look for the alternatives in place of oil-based plastic. The best alternative is the use of degradable polymers and their production has increased in the recent decades. Materials with functionality comparable to conventional plastics can now be produced on an industrial scale; they are more expensive than conventional polymers and account for less than 1 percent of plastics production (Song et al., 2009). Biopolymer is natural polymer as their source is biomass which is renewable compared to oil based polymer. The use of biopolymer is beneficial only if they are disposed though proper system by using their biodegradable features. Other recovery processes are following:

Applications of Recycled Thermoplastic Polymers

The waste generation is increasing with the each passing day but management practices are lacking far behind in the proper management of the waste (Bhattacharya et al., 2018). Different kinds of waste are produced but among them plastic waste can be recycled and various products can be obtained. The various applications of the plastic are presented in Table 3.

Recycled Polymers for Food Industry

The use of recycled polymer increases the chances of contamination which may occur during the process of production or during packaging. The contamination of these materials may be of a chemical or microbiological nature (Kolek et al., 2001). The issues related to the use of recycled plastic material raised by Food and Drug Administration (FDA) is:

Table 3. Applications of recycled plastics (Bhattacharya et al., 2018)

Plastics	Applications	References
"Polyethylene terephthalate" (PET)	"Water and soft drink bottles, food jar"	Siddique et al., 2008
Polyvinyl chloride (PVC)	"Cables, plumbing pipes"	Zare, 2017
"High-density polyethylene" (HDPE)	"Shampoo bottles, packaging"	Rahimi et al., 2017; Siddique et al., 2008
"Low-density polyethylene" (LDPE)	"Grocery bags, packaging"	Rahimiet al. 2017;Achilias et al., 2009
"Polypropylene" (PP)	"Bottle caps, medicine bottles, chips packs"	Hopewell et al., 2009; Siddique et al., 2008
"Polystyrene" (PS)	"Disposal cups, cutlery, packaging foam"	Gallop et al., 2009
"Polycarbonate" (PC)	"Food packaging, electronic goods, and defense Gadgets"	www.natureworksllc.com/~/media
"Nylon"	"Fishing nets, clothing, ropes"	www.natureworksllc.com/~/media

- Contaminants, pollutants and chemicals attached to the recycled material can get easily transferred to the food material thus can ultimately affects the health of the human beings (Siddique et al., 2008)

The following methods are recommended to avoid migration of potential contamination:

- Washing of plastic material
- Depolymerization of plastic (converting polymers into monomers)
- The migration of the contaminants can be prevented by using material having few layers in which the first layer if of recycled material and second one of pure material. The process of removing contaminants from the bottle is costly thus PET is kept on outer side of the bottle and pure plastic on inner side which acts as the barrier for the transfer of the contaminants (Kolek et al., 2001).

Recycled Polymers for Indoor Applications

The increase in the use of electrical appliances has increased the risk to the environment (Aizawa et al., 2008). So, to avoid these risks many countries have introduced recycling systems. Electronic waste includes used air conditioners, refrigerators, computers and cellular phones can be recycled and the rate of recycling of the electronic waste is increasing (> 70%) gradually (Aizawa et al., 2008; Bianchini et al., 2012).

Pyrolysis

Pyrolysis is the process which occurs in the absence of oxygen in order to break down complex polymer into simple one. It is thermal decomposition of material at temperature ranging between 300–400 °C in the presence of a catalyst (such as aluminum oxides, fly ash, red mud, and calcium hydroxide) (Miandad et al., 2016). The pyrolysis of the plastic waste results in the production of oil (45%–50%), gases (35%–40%) and tar (10%–20%) (Wong et al., 2015). The oil produced by the process of pyrolysis has similarity with that of conventional diesel. Under restricted condition, the yield of oil can be also increased approximately 80% (UNEP, 2009) Therefore, this may be an effective way to recycle plastic waste into fuels. Hence, the need is to develop the necessary facility so that huge quantity of the plastic waste generated can be converted into fuel at industrial as well as domestic level (Bhattacharya et al., 2018)

Gasification

Gasification is the thermo chemical decomposition of the plastic at high temperature. Gasification is very simple process and has gained attention as it involves air as gasification agent instead of oxygen (Vermeulen et al., 2001). In this process under controlled condition, the material is oxidized to produce syngas, which is a mixture of carbon monoxide and hydrogen with minor quantities of hydrocarbons (Scheirs, 1998; Vermeulen et al., 2001). The syngas produced can be used as an alternative in place of natural gas thus can be used for heating purpose, as a source of light and power generation (Bhattacharya et al., 2018)

Plastic Waste in Road Laying

The new concept of utilizing of the plastic for improving the quality of the roads is helpful in reducing the quantity of the plastic waste (Manju et al., 2017). Cost and the performance of the modifier determine the type of modifier to be used for the roads (Manju et al., 2017). The two procedure of modification namely dry and wet process are used for improving the quality of the roads. In dry process, plastic is firstly mixed with aggregates and then added to bitumen while plastic and bitumen is blended at the same time in wet process (Bhattacharya et al., 2018). The utilization of the plastic waste for the modification of the roads involves segregation and then shredding of the plastic waste in to the size of 2-4 mm. The waste after shredding is added to aggregate and the bitumen is heated to 160 °C in order to get good biding. Jambulingam Street in Chennai was one of India's first plastic roads built in 2002 (Manju et al., 2017).. Thus, utilization of the plastic for the construction of roads is helpful in reducing the quantity of the waste going for the treatment and is also helpful in improving the quality of the road.

Co-Processing of Plastic

Co-processing refers to the use of waste materials as an alternative fuel or raw material in industrial processes such as cement plants (Manju et al., 2017). In cement industry, the source of energy for the manufacturing of cement is provided by fossil fuels but using waste as a source of energy depends upon number of factors like composition of the waste, moisture content of the waste and economic viability (Scheirs, 1998; Vermeulen et al., 2001). The waste material received cannot be used due to its mixed nature and needs processing in order to maintain the necessary specification (calorific value, moisture content and heavy metal concentration) for the material to be used as an alternative source of energy (Bhattacharya et al., 2018)

Number of Times to be Recycled

Reusing and recycling the material again and again is helpful in increasing the life of the plastic material but can be done for limited times. Plastic cannot be recycled after crossing the optimum limit (7-9 recycling) and in some polymers, only 1-2 time recycling can be done before converting into lesser value product. The items such as clothing, fleece or even lumber cannot be recycled and may lastly end up in a landfill (Bhattacharya et al., 2018).

Bacteria and Worms That Can Degrade Plastic

Micro-organisms (bacteria, algae or fungi) may use plastic as carbon source by breaking the polymer chains. Microbial communities break the polymer chain by forming biofilms on the surface of plastic debris (Zettler et al., 2013). Some species secrete enzymes which are helpful in the cleavage of the polymer chains thus by breaking chains, the process of plastic degradation starts (Shah et al., 2008). On breaking of the plastic into smaller fragments by the process of mechanical and photo-degradation processes (Albertsson et al., 1980), the smaller fragment are easily attacked as compared to the larger one (Kawai et al., 2004). For example, the degradation of the polyethylene films increased on inoculating *Streptomyces* sp. as compared to uninoculated one (Lee et al., 1991). Similarly, the plastic waste on inoculation with some fungal increases the degradation as well as biomass accumulation in the soil (Orhan et al., 2000). Some macrofauna like wax moth (*Galleria mellonella*) can breakdown and also digest the polyethylene plastic material. may possess the ability to break up and digest certain plastic materials. The larvae of *Galleria mellonella*, can eat polyethylene, which along polypropylene is the main type of plastic found in waste (Bombelli et al., 2017). In 2016, the team of scientist from Japan identified wild bacteria (*Ideonellasa kaiensis*) which can feed on PET (polyethylene terephthalate) mostly used in the manufacturing of bottles. Therefore, more research is needed to search such organism which have the capacity to feed on the plastic thus can be helpful in the management of plastic waste (O'Brine et al., 2010).

CONCLUSION

Plastics offer numerous benefits to the society but its continuous production with improper management is adding problems to the present as well as future generations. Plastic has now entered into our every system and has also disturbed the balance of these fragile ecosystems. The need is to look for alternative or to keep check on the production as well as the consumption of the plastic in the world. The hazards related to the plastic waste can be minimized by the combined efforts of citizens, civil societies and local government. The awareness camps should be organized at mass level so the maximum number of citizens can be reached in minimum time. The problem of the generation of the plastic waste is growing day by day and is becoming a global issue therefore, it become necessary to take timely measure in order to keep this growing problem under check.

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KEY TERMS AND DEFINITIONS

Pyrolysis: It is the thermal decomposition of materials at elevated temperatures in an inert atmosphere and involves a change of chemical composition and is irreversible.

Solid Waste: Solid or semisolid, non-soluble material (including gases and liquids in containers) such as agricultural refuse, demolition waste, industrial waste, mining residues, municipal garbage, and sewage sludge.

White Pollution: The plastic things viz., plastic bottles, plastic bags, plastic silverware and so on kills the animals and degrades the quality of the environment on the earth.