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Toxic Pollutants from Plastic Waste- A Review

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Abstract

Incineration of plastic waste in an open field is a major source of air pollution. Most of the times, the Municipal Solid Waste containing about 12% of plastics is burnt, releasing toxic gases like Dioxins, Furans, Mercury and Polychlorinated Biphenyls into the atmosphere. Further, burning of Poly Vinyl Chloride liberates hazardous halogens and pollutes air, the impact of which is climate change. The toxic substances thus released are posing a threat to vegetation, human and animal health and environment as a whole. Polystyrene is harmful to Central Nervous System. The hazardous brominated compounds act as carcinogens and mutagens. Dioxins settle on the crops and in our waterways where they eventually enter into our food and hence the body system. These Dioxins are the lethal persistent organic pollutants (POPs) and its worst component, 2,3,7,8 tetrachlorodibenzo-p-dioxin (TCDD), commonly known as agentorange is a toxic compound which causes cancer and neurological damage, disrupts reproductive thyroid and respiratory systems. Thus, burning of plastic wastes increase the risk of heart disease, aggravates respiratory ailments such as asthma and emphysema and cause rashes, nausea or headaches, and damages the nervous system. Hence, a sustainable step towards tomorrow's cleaner and healthier environment needs immediate attention of the environmentalists and scientists. This review presents the hazards of incineration; open burning of plastics and effects of plastic in water and also a possibility of working out strategies to develop alternate procedures of plastic waste management.

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Keywords: Plastic, Toxicology, Pollutant, Health, Pyrolysis;

Introduction

Plastic is made up of a wide range of synthetic or semi-synthetic organic substances that are soft and can be molded into solid objects of diverse shapes. Plastics are typically organic polymers of high molecular mass and they

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often contain other substances. They are usually synthetic, most commonly derived from petrochemicals and many are partially natural (LCPP 2011).

Plastic make up an estimated 10% of household waste, most of which is disposed in landfill (Barnes, 2009; Hopewell et al., 2009) However, 60—80 % of the waste found on beaches, floating on ocean or sealed is plastic (Derraik 2002, Barnes, 2005). 2.3 billion pieces were recovered from Southern California beach over 72 hours, which weighed 30,500 kg. The majority being foams such as polystyrene (71%) followed by miscellaneous fragments (14%) pre-production pellets 10% and whole items 1%. 81% of all plastics were between 1 and 4.75mm.

As per the estimate by Central Pollution Control Board (CPCB) the plastic consumption in India, is 8 million tons per annum and about 5.7 million tons of plastic is converted into waste annually (Rathi, 2006).The increase in production and consumption of plastic materials results in a constant plastic waste increase (UNEP, 2009). As a consequence in 2007, more than 250 million tons of plastic waste was produced (Jovanovic et al. 2009). Plastic materials are predominantly not biodegradable and having a low density makes them unfit for disposal in landfills (Aguado et al., 2007). Norway and Switzerland produced about 24.9 megatonnes of plastic waste (Mudgal *et al*., 2011). In 2009, around 230 million tonnes of plastic were produced and about 25% of these plastics were used in the European Union (EU) (Mudgal *et al*., 2011). This global figure has been increasing by an average rate of 9% since 1950 to a peak of 245 million tonnes in 2008. Polybags and other plastics items except PET in particular have been a focus, because it has contributed to host of problems in India such as choked sewers, animal death and clogged soils (PESD 2007)

Future application for plastic increases and its use continues to grow in developing and emerging economies (Global Industry Analysts, 2011). Without appropriate waste management, increased plastic waste, will add to the back log of plastic waste already in existence. There is no agreed figure on the time that plastic takes to degrade but it could be hundreds or thousands of years (Kershaw et al., 2011).

As per the EU studies, suggested, increased use and production of plastic in developing and emerging countries is a particular concern, as the sophistication of their waste management infrastructure may not be developed at an appropriate rate to deal with the increasing levels of plastic waste. Increase in temperature and environmental conditions may affect the degradation of plastic into secondary microplastics or the release of chemicals contained or transported on plastic waste. Secondary microplastics are those formed from breakdown of larger plastic materials (Arthur et al., 2009).

Plastic waste is a global problem, but with regional variability. One source of air pollution is burning of plastic waste in the open field and warming up of the surrounding air. This is also true for plastic waste in the marine environment in terms of water pollution and liberation of chemicals contained.

The property of plastic makes it so valuable and also its disposal becomes problematic, such as its durability, light weight and low cost. Most of the time, plastic is thrown away after usage; hence being durable they persist in the environment. Plastic has become ubiquitous and India is no exception. Most of the times, the Municipal Solid Waste (MSW) containing about 10-12% of plastic is burnt, releasing toxic gases into the environment which include substances like Dioxins, Furans, Mercury and Polychlorinated Biphenyls. Only few studies on the impact of such toxic gases have been performed in India. Landfills have contributed to nearly 20% of Green House Gases (GHG) followed by fossil fuels. Currently, landfills are overloaded with waste dumps and wastes being burnt along with plastic bags are posing health risks. An immediate measure to address them is the need.

Plastic waste has the ability to attract contaminants, such as persistent organic pollutants (POPs). This is so in the marine environment since many of these contaminants are hydrophobic, plastic could potentially act as a sink for contaminants, making them less available to wildlife, particularly if they are buried on the seafloor.

Biomass accumulation on the plastic or biofouling is likely to increase the density of plastic. Plastic contains chemicals or additives to give it certain properties. There is a wide range of additives, but probably the most relevant

to ecology and human health are Bisphenol A, Phthalates and Brominated Flame Retardants. Bisphenol A and Phthalates are rapidly metabolized once ingested but their concentration within the tissues varies between species for the same exposure.

Conditions within landfill may cause the chemicals contained within plastic to become more readily available to the environment a major concern in developing countries. Just as plastic waste moves on the surface of the sea and from the sea to the coast, it can also move vertically. Biofouling with micro-organisms, plants or algae onto plastic debris causes it to become heavier and eventually sink. Sample of plastic debris in the western North Atlantic Ocean and plastic in the sea had a different specific gravity to plastic debris found at the beach, suggesting that plastic undergoes changes when it is at sea. The presence of plastic in sea on the surface or below may help in identifying potential hazards for either surface feeding or seafloor feeding wildlife. Establishing the size, mass and composition of plastics that persist in the ocean is important for understanding the impact of plastics (Moret-Ferguson et al., 2010). Polyethylene was the most common type found in sea and the study suggested further research is needed to determine if lighter plastics, such as polyethylene, are more readily transported by winds and currents than heavier plastics such as Poly vinyl chloride (PVC) which tends to sink and so is subject to different patterns of transportation than plastic on the surface.

Thermal utilization and dumping in landfills: Current disposal methods -Disposal of waste into landfills implies an irreversible loss of valuable raw materials and energy. The incomplete combustion of Polyethylene (PE), Polypropylene (PP) and Polystyrene (PS) during thermal utilization can cause high concentrations of carbon monoxide (CO) and noxious emissions, while PVC generates dioxins, carbon black and aromatics like pyrene and chrysene. Hazardous emissions can include bromide and color pigments that contain heavy metals like chromium, copper, cobalt, selenium, lead and cadmium. Open burning of MSW and landfill fires to emit 10,000 grams of dioxins/furans into Mumbai's lower atmosphere every year (NEERI 2010).The waste plastic finds its way into drains, open lands, rivers, railway tracks and coasts (MOEF 2011). Despite waste management efforts to manage wastes, more than 91% of MSW collected is still landfilled or dumped on open lands (DEA, MOF 2009).

Effect of primary and secondary sources of micro plastics to the environment is to be addressed urgently. (Arthur et al., 2009). More investigation needs to go into what level of exposure is caused by plastic waste and chemicals from plastic which may have an impact on humans and animals has to be worked out. Those at the top level of the food chain would be exposed to greater levels of chemicals.

Objective of the study include: Effect of plastic waste and its pollutants on health and Toxic pollutants found in plastic waste.

Methodology

Fourier Transform infrared spectroscopy, can detect particle less than 1.6 µm. Macroplastic can be further categorized according to type of object, for example, bottle, bag, lid etc., The bio concentration factor is the concentration of a chemical within the tissue of the species compared with its concentration in the surrounding environment. If badly managed, recycling processes can cause the release of chemicals from plastics into the environment and subsequent impact on human health. There has been some concern about heavy metals such as CD, in plastic especially in children toys, plastic crates and pellets.

Use of plastic in mobile phones indicates its plastic components contain several toxic substances (Nnorom&Osibanjo, 2009). If such quantities increase and open burning practiced in developing countries, there is potential for environmental pollution and human health impact.

More land –based research on plastic waste and research on chemicals in landfills, particularly measuring level of additives leached into environment is needed (Oehlmann et al., 2009).

Plastic waste has several impacts on the health of ecosystems and humans. Although there is little research on the specific impacts of plastic waste on land-based wildlife, there is concern that incorrectly managed landfills could

lead to either the escape of plastic waste or the escape of landfill leachates containing the chemicals associated with plastic. Recycling of plastic particularly in developing countries can cause the release of chemicals into the environment for example the burning of plastic coated wired to extract metal. Effects associated with chemicals that are part of plastic or transported by plastic may also be sub-lethal. Plastic ingestion could increase the buoyancy of fish making it difficult for mesopelagic fish to return to deeper waters (Boerger et al., 2010).

The impact of chemicals on humans and ecosystems is either due to its presence in plastic or plastic waste on transportation. Plastic is not inert, but contains several chemicals with toxic potential and it also has the potential to transport contaminants. The threat posed by hazardous brominated compounds act as carcinogens and mutagens requiring immediate attention. Dioxins are the lethal POPs and its worst component, 2,3,7,8 tetrachlorodibenzo-p-dioxin (TCDD), commonly known as agent orange is a toxic compound which causes cancer and neurological damage, disrupts reproductive, thyroid and respiratory systems. Burning of plastic waste increases the risk of heart disease, aggravates respiratory ailments such as asthma and emphysema and cause rashes, nausea or headaches, and damages the nervous system. These vapors can damage eyes and mucous membranes. Additives used as heat stabilizers, frequently contain heavy metals such as barium, lead and cadmium, sometimes in combinations. Lead and cadmium are the most serious environmental pollutants and have effect on human health depending on their concentration. When present at or above specific concentrations, they interfere with processes in plant and animal tissues, and in the soil. PVC contains chlorine which can be released during burning as hydrochloric acid (HCl). High concentrations of these affect the human respiratory system. Pure PVC contains 58% chlorine when plasticizers are added; it contains about 49% chlorine.

Burning of plastic bags releases chemicals into the air, causing serious lung damage and other long-term health problems. People with lung diseases such as asthma and chronic obstructive pulmonary diseases, single exposure to this smoke can worsen their disease.

Results and Discussion

Negative impacts: The usage of certain plastics also poses health risk. Further, burning of PVC liberate halogens which may pollute the air. For instance any plastic burnt in open will produce dioxins or toxic substances. Many of the impacts of plastic waste are sub-lethal, but in conjunction with other impacts from plastic waste or environmental effects such as oil spills or harsh weather conditions, they could become lethal.

Polystyrene is harmful to Central Nervous System. Burning of plastic leads to severe health risks such as heart diseases, aggravates respiratory ailments such as asthma and emphysema and cause rashes, nausea or headaches, damages in the nervous system kidney or liver, in the reproductive and development system. Dioxins settle on crops and in our waterways where they eventually enter into our food, get into our body (WECF, 2004).

The by-products of plastic combustion are airborne particulate emission (soot) and solid residue ash (black carbonaceous colour). Several studies have demonstrated that soot and solid residue ash possess a high potential of causing health and environmental concerns, especially Volatile organic compounds (VOCs), semi- VOCs, smoke (particulate matter), particulate bound heavy metals, polycyclic aromatic hydrocarbons (PAH's), polychlorinated dibenzofurans (PCDF's) and dioxins (Valavanidid et al 2008). This can travel thousands of kilometres, depending on prevailing atmospheric conditions and enter our food chain. Significant amount of pollutants of environmental and health concern including carcinogens such as PAH's, nitro-PAH's and dioxins have been identified in the airborne particulate emission. These particulates are highly mutagenic (Lee et al., 1995). PAHs in the range of 8-340 ppm have been observed in the soot which is significant enough to cause cancer (Valavanidid et al 2008).

High concentration of persistent free radicals (unstable and highly reactive) both in the soot and the solid residual ash are considered to be very important in the creation of adverse health effects especially to human lungs (Simoneit et al., 2005). Combustion of PE (both low LDPE and high density HDPE) at different operating conditions detected VOCs and semi VOCs especially olefins, paraffin, aldehydes and light hydrocarbons (Valavanidid et al., 2008). Benzene amongst VOC's is known carcinogen and released during plastic combustion.

Di(2-ethylhexyl) phthalate (DEHP) is one of the compounds among the plasticizers used in plastic manufacturing that has been descried by USEPA (United States Environmental Protection Agency) as a probable human carcinogen, a potential endocrine disruptor and is believed to be harmful by inhalation, generating possible health risks and irreversible effects released during combustion of plastics. During extrusion process several substances such as additives, may be released from PVC, vinyl chloride and HCl. Incineration must be complete i.e. combustion, burning plastic within the waste may release considerable quantities of polluting substance (Brian 2012). One way of dealing with waste is to incinerate it fully. With complete combustion almost 90% of plastic material is reduced to carbonic acid, CO_2 and water, but PVC is an exception to this rule, since the chlorine it contains produces HCl when burned.

Incomplete combustion of PE, PP and PS and PVC can cause further problems as CO and smoke may be produced. As a result of incomplete combustion of PVC, dioxins and other hazardous substances may be formed. These serious difficulties can be overcome by keeping the moulding period very short and by adding a heat stabilizes.

Bisphenol A – There has been ongoing debate about the use of Bisphenol A in Europe, and the EU has now banned the placing on the market and importing of polycarbonate baby bottles containing Bisphenol A. Although this ban will affect the type of new plastic waste entering the environment it will not affect debris already in the environment.

Phthalates – The use of some phthalates has been restricted in the EU for use in children's toys since 1999, Di (2-ethylhexyl) phthalate (DEHP), Benzyl Butyl Phthalate (BBP) and Dibutyl phthalate (DBP) are restricted for all toys; Diisononyl phthalate (DINP), Diisodecyl phthalate (DIDP) and di-n-octyl phthalate (DNOP) are restricted only in toys that can be taken into the mouth. The restriction states that the amount of phthalates may not be greater than 0.1 percent mass per cent of the plasticized part of the toy. There are no other specific restrictions in the EU, about Flame retardants – In 2008 the EU banned several types of Polybrominated diphenyl ethers or PBDEs when it was discovered that they were accumulating in breast milk. This is of particular concern as is their release through the burning of electronic and electric waste when it is dismantled / recycled in uncontrolled environment.

The most concerning issue is the impact of chemicals associated with plastic waste. There are several chemicals within plastic material itself that have been added to give it certain properties such as Bisphenol A, phthalates and flame retardants. These have negative effects on human and animal health, mainly affecting endocrine the endocrine systems. Toxic monomers have been linked to cancer and reproductive problems.

Case studies: European Economic Area (EEA) review (Herczeg et al., 2009) of the Directive in five EU countries and one sub national areas (Estonia, Germany, Finland, the Flemish Region of Belgium, Hungary and Italy), indicates that there has been drop in the amount of waste going to landfill from 1999 – 2006.

Separate data from a Plastic Europe report indicate that despite a 3% annual growth in the past decade for post-consumer plastic waste in EU15, landfill, amounts have increased by only 1.1% per year, this is due to increase in recycling and energy recovery.

Kommunenes Internasjonale Miljøorganisasjon (KIMO), Sweden has assessed the abundance of microscopic plastic particles that are less than 4.5mm in Swedish west coast water (Noren, 2007). A considerably higher amount of microplastic particles was found using an 80µm mesh, compared to using a 450µm mesh, to concentrate the water samples. Up to 100,000 times higher concentrations, (150- 2400 per m^3), of small plastic debris were retained on an 80µm mesh with the higher concentration (102,000 per m^3). Found locally in the harbour outside a polyethylene production plant.

Over ten days of sampling, the research found on average 484 pieces of plastic that were deposited on the beach daily. Polyethylene has the potential to degrade more readily than polypropylene, as it is more conducive to the oxidation process. There is a possibility that additives may provide preferential site for continued degradation, as indicated by the small patches of heavily oxidized areas in otherwise intact plastic pellets. PE and PP are inert

materials (Mewis, 1983). Under the influence of light, heat or mechanical pressure they can decompose and release hazardous substances. Styrene in Polystyrene and vinyl chloride in PVC are toxic. Pigments or colorants may contain heavy metals that are toxic to humans such as chromium, copper, cobalt, selenium, lead and cadmium are often used to produce brightly coloured plastics. Cadmium is used in red, yellow and orange pigments. Additives used as heat stabilizers contain heavy metals like barium, tin, lead and cadmium (Vivek 2014).

Sea turtles can confuse plastic bags for jelly fish (Derraik 2002, Gregory, 2009).Recent research on plankton-eating fish in the North Pacific Gyre (Boerger et al., 2010) has indicated that 35 per cent had ingested plastic, averaging 2.1 pieces per fish. However, Davison & Asch (2011) found only 9.2 per cent of sampled mesopelagic fish contained plastic in North Pacific.

Cat fish in an estuary in northeastern Brazil indicated that between 18 and 33% of individuals had plastic debris in their stomach, depending on the species of cat fish (Possatto et al., 2011). Cat fish could be a good species for monitoring plastic ingestion in rivers, as they are both predators and prey to large fish.

Synergic or interactive effect of plastic debris with other impacts such as bioaccumulation of mercury and cadmium in Franciscanadolfins, alongside ingested plastic waste and entanglement in fishing nets (Denuncio et al., 2011).

Work on beach clean –ups to ban on plastic waste disposal at sea, targets for proper and efficient waste management and plastic recycling to useful products.

The Oslo Paris Convention for Protection of the Marine Environment of the North-East Atlantic pilot project on monitoring marine beach litter in the North Sea was one of the first region wide projects in Europe to develop a standard method to monitor marine litter found on beach (OSPAR, 2007).

Applying the polluter pays principle, in terms of littering and illegal dumping and disposal, applying the user pays principle in terms of tourist taxes, car parking fees, port reception and ship berthing fees can go towards beach cleaning and improving waste infrastructures. Tradable permits are not appropriate for littering.

Incentives to fishermen for reporting on and removing debris from sea with fishing for Plastic project (in the save our North Sea programme), which pays fishermen to remove plastic should be considered.

Policy based on findings about chemicals within plastics has already been made, such as the ban on Bisphenol A but for chemicals with less clear impact (especially if their effects are sub –lethal or sub-toxic but could still accumulate other initiatives may need to be developed).

Plastic waste does require responses from several policy areas. Marine litter and plastic waste is a priority on the EU policy agenda.

Banning of some harmful chemicals contained in plastic, such as Bisphenol A and some phthalates, has already occurred, but for other restriction may have to be voluntary. A harmonized industry-wide effort is needed to communicate information about chemicals used in plastic, alongside public education about the chemicals.

In India Landfills pose threat as plastic in MSW is burnt in most of these places as the waste is dumped together contributing to GHG emission. This seriously draws attention.

Conclusion

The ill effects of Climate Change have already begun to be felt. Toxic substances are released via burning from plastics, open combustion, incineration, posing a threat to the surrounding areas including vegetation and health of individuals. Proper development of policy with respect to chemical exposure caused by plastic must be set in place with encouraging research in this direction. A sustainable step towards tomorrow’s cleaner and healthier

environment is the need of the hour. This would help the masses to be aware of the severity of the problem and go for technologies which can pose less risk hazards on human health with reference to developing nations. Thus the scientific community needs to think about the cumulative environmental exposures that may harm human health. Instead of combustion and incineration, pyrolysis can be another alternative method which is known to produce less toxic substances if conditions are appropriate with variable amounts of potentially useful by-products. Recycling is better minimizing stress on the resources and utilizing the by-products, increasing sustainability. Introducing recycling programs and study will considerably make a great change. Several pyrolysis systems have been initiated and people realized that it is best option, but proper scientific data and design of unit and follow up studies are very few.

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