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THE LONG TERM HEALTH RISKS POSED BY THE CHEMICALS IN PLASTIC AND THE WAY OUT: A REVIEW

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Abstract

Plastic is a kind of material that is commonly known and used in everyday life in many forms and becomes an important part of every one's life. During its manufacture and compounding, other chemicals are often used, including initiators, catalysts, solvents and a wide range of additives in plastic products for enhancing polymer properties and prolonging their life. Within plastics, lie numerous chemicals and toxic substances, such as Bisphenol A (BPA), phthalates, styrene, brominated flame retardants, and polyfluorinated chemicals, alkylphenol, dioxin, uv-stabilizers and polyvinyl chloride all of which pose significant hazards to human health. Unfortunately, people often utilize plastic without recognizing its adverse effects on their well-being. The consequences of plastic usage encompass a wide range of health issues, including endocrine, thyroid and immune system disruption, reproductive disorders, birth defects, cardiovascular ailments, breast growth and testicular cancers. Implementing appropriate regulations and guidelines for the production and utilization of plastics can mitigate their detrimental impacts on human health.

Keywords: Plastic; Health, Risk, Chemicals; Bisphenol A; Phthalates

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1. Introduction

Plastic is the most useful synthetic 'manmade' substance, made up of elements extracted from the fossil fuel resources. It is a kind of material that is commonly known and used in everyday life in many forms and becomes an important part of every one's life. To define plastics at molecular level, it is a kind of organic polymer, which has molecules containing long carbon chains as their backbones with repeating units created through a process of polymerization. The structure of these repeating units and types of atoms play the main role in determining the characteristics of the plastic. These long carbon chains are well packed together by entanglements and Van der Waal forces forming a strong, usually ductile solid material (Koushal, et al, 2014). During the manufacture and compounding of plastics other chemicals are often used, including initiators, catalysts, solvents and a wide range of additives in plastic products for enhancing polymer properties and prolonging their life. The additives are not covalently bound to the polymer and are therefore susceptible to migration during heating or long term storage (Noopur et al., 2014) and eventually lead to human exposure via mouthing of products and direct dermal contact, humans and biota can also be exposed to chemicals indirectly when plastic-associated chemicals are released into air, soil, or water, via inhalation of air or consumption of contaminated food and drinking water. They can also be released from plastics during the various recycling and recovery processes (SAICM, 2020). The plastic materials are so thoroughly integrated into our daily lives that we are at a point where it is impossible to imagine a day without using them. Ranging from the hot tea/coffee cup to a cold drink bottle, covers of the books to the refrigerator, the keyboard of the computer to the casing of a cell phone, the car dashboard to the chewing gum, plastic materials are all around us. Although the fact cannot be refuted that plastic has made life easier and interesting, it is potentially hazardous to both the environment and human health, and this cannot be ignored.

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2. Type of Plastics

2.1 Natural Plastics

Natural plastics are natural substances which are classified as plastics due their property whic h permits them to be molten, molded and shaped easily when subjected to heat. For instance, amber is a fossil pine tree resin that is commonly used in the production of jewelry.

2.2 Synthetic Plastics

Synthetic plastics are obtained when the molecular structure of carbon-based materials such as coal, crude oil or gas undergoes decomposition or 'cracking' process. This process which involves the subjection of such materials to pressure and heat forms the basic procedure used in petrochemical refineries for manufacturing most of the plastics commonly found around today. There are two other categories of synthetic and semi-synthetic plastics which are classified based on the way in which the plastic material will react after heating. These two categories are;

2.3 Semi Synthetic Plastics

Semi synthetic plastics are obtained from the combination of natural materials with other substances. For instance, cellulose acetate is the product of reacting cellulose fiber with acetic acid which is widely applied in cinema film production.

2.4.1 Thermoplastics

Any plastic materials whose property allows it to get soft and melt under heat and to be shaped or reshaped by taking the shape of a desired designed mold when cooled. The most distinguishing property of thermoplastics is that when reheated they can molten again. Styrene's and acrylics are the most common and perhaps the largest occurring examples of thermoplastics.

2.4.2 Thermosetting plastics

Thermosetting plastics cannot be softened or molten when reheated, although at the first instance they will mellow and melt under high temperature. When molten they can be molded into shapes into which they were placed before cooling but afterwards they become permanent in the shapes into which they were set and any attempt to further subject them to heat will only make them brittle or burn. Examples includes polyester resins which are used largely for glass reinforced plastics work and those mostly employed in the manufacture of Formica for kitchen work surfaces such as melamine formaldehyde (Kehinde et al., 2020).

2.5 Categories of plastic

2.5.1 Polyethylene terephthalate: Safe and recyclable, plastic bottles and containers made of it used for water, juice, soft drinks and peanut butter packaging. Its airtight nature prevents the entry of oxygen, ensuring that the contents of the bottles remain uncontaminated. It contains no harmful bacteria or phthalates, but they may contain antimony trioxide which is considered as a potential carcinogen when present in the human body.

2.5.2 High-density polyethylene: Safe and recyclable, used for the manufacturing of packages for shampoo, detergents and milk, as well as plastic toys. It is safer than any other plastic material especially the transparent type.

2.5.3. **Polyvinyl chloride:** Harmful and toxic if used for long time. It is commonly abbreviated PVC and used in the manufacturing of plumping pipes, bathroom curtains, toys, and transparent plastic wraps for meat and cheese. It is widely used because of its cheap price, so it is considered the most dangerous type of plastic.

2.5.4. **Low-density polyethylene**: Proportionally safe, recyclable, used for the manufacture of CDs, bottles and grocery bags.

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2.5.5 Polypropylene: is one of the best and safest types of plastic, suitable for cold and hot liquids and other products (unharmful) used in manufacturing of food containers, plates, medicine bottles and all food related products. It is recommended that all food containers should be made of this substance, especially children's food containers used for school meal packaging, and water bottles reused for multiple times. Using disposable plastic more than once turns them to be toxic if re-filled again.

2.5.6. Polystyrene: Dangerous and unsafe, used for burger, hotdog and teacups packaging. This material has impact on the ozone layer because it is made of harmful Chlorofluorocarbons gas.

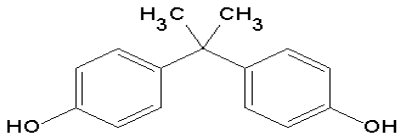
2.5.7. **Others**: Such material does not come under any category of the above mentioned types of plastic. It can be mixture or compound of the six previous types. It is a source of debate among the scientific community as many international companies started to produce toys and baby-feeding bottles made of it (UNEP, 2023).

In the process of plastic production and use major disposal problems arise which leads to poo r aesthetics, fire hazards, health hazards, and energy shortages.

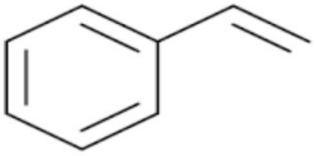
3. Harmful Chemicals in Plastics and the Health Risk Associated with them

3.1 Bisphenol A (4,4-dihyroxy-2,2-diphenylpropane) : is a building block of polycarbonate plastic and it is used in food packaging and canned food. BPA exposure may disrupt normal breast development and also cause breast cancer in later life. BPA is also linked to have an adverse effect on brain development of girl child, if the mother is exposed to BPA during pregnancy. Researchers from Harvard school of Public Health and Centers for Disease Control and Prevention measured BPA level in the urine of 244 mothers at the various times in pregnancy and in their children at different times after birth. They found that the mother who was having high BPA level during pregnancy tended to have 3 years old girl with more

anxious and depressed behavior and poor emotional control. But the similar behavior changes were not seen in boys whose mother was having high level of BPA and the reason is still unknown. The researchers think and guess that as BPA is endocrine disrupting chemical and may acts like estrogen or antiestrogen, so it may alter the effect of sex hormone in girls. It is advised that pregnant women should avoid BPA exposure by not using canned and packaged food, Izhar et al., (2015). The structure of bisphenol A is as shown below.

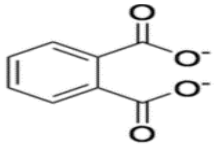


3.2 Styrene: can leach from polystyrene plastic and it is commonly found in disposable cups and bowls, Styrofoam food trays, egg containers, opaque cutlery and carryout containers. International Agency for Research on Cancer has classified styrene as a possible human carcinogen. Studies found that styrene increases the risk of cancer of the pancreas and of esophagus among styrene workers. Styrofoam is actually a brand name of polystyrene. The migration of styrene from food containers and packaging to human body through food is documented in 1973 and 1976. In a single use of polystyrene cup approximately 0.025 % styrene can be transferred to the human body with hot or cold beverage. If someone drinks water, tea or coffee with Polystyrene cup four times a day for three years he would consume one Styrofoam cup-worth of styrene with this beverage. It has been observed that styrene migration depends upon fat contents in the food, heat, acidity and presence of ethanol and presence of Vitamin A. Soup Beverages that are higher in fats (Breast Cancer Fund).



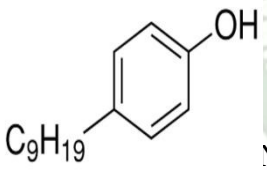
Styrene

3.3 Phthalates: are chemical additives widely used to produce or promote flexibility and to reduce brittleness in plastics. Phthalates are used as plasticizers in PVC consumer, medical, and building products, as matrices and solvents in personal care products, and as fillers in medications and dietary supplements, food and beverage packaging, and children's toys. The phthalate DEHP ((di-(2-ethylhexyl)phthalate)) is common in medical devices such as plastic tubing. Some phthalates are restricted in the European Union and are classified as substances of very high concern. Daily human exposures via oral ingestion, inhalation, and skin contact are common. Phthalates frequently leach from items such as food packaging, cosmetics, body care products, and toys into the environment and into products that humans use and consume. The most common routes of exposure are via oral ingestion from food packaging and the use of cosmetic products, but high levels of phthalates are also present in household dust. They are metabolized quickly and are present in 90-100% of amniotic fluid samples from second-trimester fetuses, cord blood samples from newborns, breast milk from nursing mothers, and even in human ovarian follicular fluid. A review integrating results from in silico, in vitro, in vivo, and epidemiological studies concluded that phthalate exposure is associated with reproductive disorders with potential transgenerational or multigenerational effects (Hliniskova et al. 2020). Phthalates have been found to deposit in the fatty tissues of the body, and also causative factors of human diseases like male reproductive dysfunction, breast growth and testicular cancers (Koushal 2014).



Phthalate

3.4 Alkylphenols: Nonylphenol (NP) is commonly used as a stabilizer and intermediate in plastics production. 4-tert-Octylphenol has major uses in formaldehyde resins. NP is an endocrine disrupting chemical and suspected to be toxic to reproduction. Biomonitoring studies have demonstrated the widespread human exposure to NP (Ringbeck et al. 2022). 4-tert-Octylphenol is a potential environmental pollutant and exhibits estrogenic and anti-androgenic activity in human reporter cell lines (Paris et al. 2002).



Nonylphenol

3.5 Per- and polyfluoroalkyl substances (PFASs): are composed of thousands of synthetic organic fluorinated substances that contain at least one fully fluorinated methyl or methylene carbon atom (without any H, Cl, Br or I atom attached to it) (OECD 2021). Prominent examples of long-chain PFASs are the perfluorocarboxylic acids (PFCAs) with carbon chain lengths C8 and higher, including perfluorooctanoic acid (PFOA), and the perfluoroalkane sulfonic acids (PFSAs) with carbon chain lengths C6 and higher, including perfluorohexane sulfonic acid (PFHxS) and perfluorooctane sulfonate (PFOS). A major use of PFOS, PFOA, and related substances (precursors) was in the manufacturing of side-chain fluorinated polymers such as fluorinated (meth)acrylate polymers, fluorinated urethane polymers, and fluorinated oxetane polymers (Buck et al. 2011). These polymers are used as linings for food containers and wrappers, and as surface treatments for plastic fibers in carpets, furniture and other textiles to repel water, oil, and dirt (Glüge et al. 2020). In animal studies, PFOS has

been shown to cause cancer, neonatal mortality, delays in physical development, and endocrine disruption (Luebker et al. 2005). Higher levels of PFOS and PFOA are associated with delayed pregnancy (Fei et al. 2009) and reduced human semen quality and penis size (Joensen et al. 2009).

3.6 Dioxin: Dioxins are considered the world's most toxic substances, byproducts of industrial and combustion processes and occur in the production of plastic products with brominated flame retardants (BFRs) and when plastics with BFRs are incinerated or heated in a recycling process to be re-molded into new products. There is no safe level of dioxin exposure. They are fat soluble, bind to soils, and can accumulate in animal and human fatty tissues.

Dioxin exposures can occur through oral, dermal and inhalation routes. Children mouthing toys made of recycled plastic that derives from e-waste are at risk of dangerous health effects from the toxic material. Dioxin contamination of local food chains has been documented in communities where e-waste shipments are dumped and incinerated, landfills where plastic waste accumulates, and where plastic waste is incinerated for fuel at levels that are comparable to dioxin hotspots.

Dioxin exposures affect brain development, disrupt thyroid and immune system functions, and are associated with increased risk of multiple cancers, and immune system damage (ipen, 2020).

3.7 Flame retardants are a class of additives used to reduce flammability and the spread of fire in plastics. They are used in many varied consumer products, such as electronic devices, vehicles and other transportation media, furniture, insulation foams, and certain textiles. The main flame retardants used in plastics includes:

(i) Brominated and chlorinated flame retardants (BFRs/CFRs), often used with antimony (Sb) as a synergist. BFRs includes polybrominated diphenyl ethers (PBDEs), decabromodiphenyl ethane (DBDPE). Examples of CFRs include short-, medium- and long-chain chlorinated paraffin and dechloranes (Sverko et al., 2011)

(ii) Organophosphorous flame retardants includes tris(2-chloroethyl)phosphate, tris(1,3-dichloroisopropyl)phosphate, tris(2-chloroisopropyl) phosphate, tris(2-butoxyethyl) phosphate

(iii) Inorganic flame retardants such as aluminum and magnesium hydroxides and boron.

The PBDEs ubiquitous, persistent, bioaccumulative and exhibiting various modes of toxicity including endocrine disruption, developmental neurotoxicity, and reproductive disorders, tetrabromobisphenol A is a carcinogen. OPFRs such as TBOEP and TDCPP exert several toxicological effects and are associated with health problems, including adverse neurological, reproductive and endocrine-disrupting effects (Broche et-al., 2021, UNEP, 2023).

3.8 Uv Stabilizers: UV stabilizers prolong the lifespan of plastics by protecting them from photo-degradation initiated by UV light absorbing radiation before it reaches photosensitive moieties in the polymer. They decrease weatherability through light stabilization or UV absorption. Benzophenones, benzotriazoles (BZTs), hindered amine light stabilizers (HALS), and their combinations are the most common UV stabilizers for the plastic industry. UV stabilizers can leach from food packaging materials into our food and disrupt endocrine function, impeding normal development and inducing estrogenic effects (Ipen, 2020).

3.9 Polyvinyl chloride (PVC): is named “the poison plastic” because of the lifecycle of the plastic, which is toxic from start to finish. It is chlorine-based, so when it is manufactured or burned, it results in the generation of dioxin, a known human carcinogen. It also contains

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many toxic additives such as phthalates, lead and cadmium, which leach out during use. PVC is used to make products from bottles to shower curtains to children's toys. The production, use, and disposal of vinyl have been linked to several healthy concerns, including reproductive abnormalities, damage to the immune and neurological systems, hormone disruption, infertility, and cancer. PVC is used in numerous consumer products, including adhesives, detergents, lubricating oils, solvents, automotive plastics, plastic clothing, personal-care products (such as soap, shampoo, deodorants, fragrances, hair spray, nail polish), as well as toys and building materials (Noopur et al., 2014).

4.1 WARNINGS

The following tips should be followed to be safe from the health effects of plastic chemicals.

▪ Do not use any plastic containers or utensils in the microwave.

▪ Do not use plastic bottles to keep water in the refrigerator.

▪ Do not put food wrapped with plastic in the microwave.

▪ Be aware that the indiscriminate burning of plastic bags produces carcinogenic dioxin.

▪ Do not use plastic containers to save food especially pickle, acid and fatty food because such practice causes plastic to decompose, and toxic carcinogens to enter the body (*Harmful effects of plastic n. d.*).

4.2 Ways and means of reducing the use of plastic in our livelihood

To be on the safer side, use the following alternatives instead of using plastic materials which may interfere with our well-being.

1. Use paper or cloth bags instead of plastic bags.

2. Reuse plastic bags many times to reduce consumption, hence, regulate their production.

3. Use glass containers such as Pyrex.

4. Use of plastic bags can be reduced through codification by imposing heavy taxes on their production

5. Compliance with proper criteria and standards on the production of plastic bags makes the bags thicker, more durable and biodegradable.

6. Reduce the use of plastic-wrapped products.

7. Mothers should be cautious not to use plastic bottles for feeding their babies.

8. Do not buy plastic toys which children can chew, and replace them with toys made of natural materials.

9. Do not buy or use plastic cups, plates or spoons, especially the disposable single-use ones.

10. If you select between different plastic products, choose the product that can be reused or recycled.

11. Do not take more plastic bags than you need when shopping.

12. In case you buy a product in a plastic can or bottle, reuse it for other purposes instead of disposal.

13. Avoid using plastic cups made of rigid polystyrene in drinking tea, coffee and other hot drinks. Use paper or glass cups instead.

4.3Alternatives for the use of Plastic Materials

Biodegradable Plastic: refer to polymeric material that are capable of undergoing decomposition into carbon dioxide, methane, water, inorganic compounds, or biomass in which the predominant mechanism is the enzymatic action of microorganisms, that can be

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measured by standardized tests, in a specified period of time, reflecting available disposal condition (Kirubadevi and Pavithra, 2020). Although traditional plastics can be reused or recycled, they take many decades and even more than two hundred years to decompose, leading to serious environmental problems. The solution for this problem is to produce oxo-biodegradable plastics (oxo-bio) by using the degradable to water (D2W) additive during the standard production process of plastics. The impact of the additive is therefore negligible and there is no special training required for workers. There is no change involved to the standard plastics manufacturing processes and no impact on line speeds either during manufacture or in use (Harmful effects of plastic n. d.). The following table shows some examples of plastic products and suggested alternatives for use.

Products made from plastics	**Suggested biodegradable alternatives**
Single-use plastic shopping bags	Cloth bags, bamboo baskets
Items packed in plastic	Glass, metal containers
Disposable cups	Stainless steel, glass cups
Disposable straws	Straws of glassware, stainless steel, bamboo, silicone
Plastic brush and scrubber	Use a natural sponge, luffah, coir
Storage containers, bags.	Silicone bags, metal, wood, glass containers
Disposable tableware	Metal, ceramic, glassware, bamboo
PVC, plastic foam board	Wooden, metal board
Polyester carpet	Wool, cotton, jute, wooden flooring

4.4 Reduce use of single-use plastics

Single use plastics include plastic bags, water bottles, straws, cups, utensils, dry cleaning bags, take away containers and any other plastic items that are used once and discarded. This can be done by refusing any single use plastics that you do not need e.g straws, plastic bag, takeaway utensils.

5.0 CONCLUSION

Research has shown that exposure to toxic chemicals used in plastic production has harmful effects on human health but unfortunately, many people unknowingly use these toxic plastics. The detrimental impact of plastics on human health is evident in reviews. It is crucial for the government, law enforcement agencies, and health authorities to prioritize sustainable production, usage, and disposal of plastics. High-risk phthalates should be banned and regulated, especially in consumer products and those in contact with children. Bisphenols should be prohibited in materials that come into contact with food, beverages, children, and phased out in other consumer products. Every company has a responsibility to reduce unnecessary plastic consumption. Comprehensive information about chemicals in consumer products is essential to raise public awareness.

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