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TOXIGENIC EFFECTS OF PLASTICS ON HUMAN HEALTH

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ABSTRACT

Plastics are inexpensive, lightweight, strong, durable, corrosion-resistant materials, with high thermal and electrical insulation properties. These properties have made the plastics the most used material for food and liquid packaging. As a consequence, the production of plastics has increased substantially over the last 60 years from around 0.5 million tonnes in 1950 to over 260 million tonnes today. Packaging maintains the benefits of food processing after the process is complete, enabling foods to travel safely for long distances from their point of origin and still be wholesome at the time of consumption. However, plastics also pose health risks. Of principal concern are endocrine disrupting properties, as triggered for example by bisphenol A and di-(2-ethylhexyl) phthalate (DEHP). Research has shown that these compounds can leach from plastics into the food and drinks that we consume - more so if they are heated to high temperatures, raising additional concerns about the kinds of plastics that are used as containers in microwave ovens. Looking beyond the essential services that plastics provide to humanity and their associated human health risks, evidence abounds for plastics' potential to pollute and disrupt important natural processes and quality of life and its continued use at accelerating rates is unsustainable and will cause a significant burden for future generations.

Key words: Toxigenic effect, Plastics.

INTRODUCTION

Plastic is the most useful synthetic 'manmade' substance, made up of elements extracted from the fossil fuel resources. It has made possible most of the industrial and technological revolutions of the 19^{th} and 20^{th} centuries. During the past 30 years plastic materials have been used widely in food, clothing, shelter, transportation, construction, medical and leisure industries because they are light weight, low cost, extremely durable and relatively unbreakable[1]. Most common plastics known as polythene or polyethylenes are thermoplastic materials that are produced primarily by the catalytic polymerization of ethylene gas (C_2H_4) at elevated temperatures (T) and pressures (P).

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The polyethylene molecules usually contain branches of various lengths. Of all the hydrocarbon polymers, polyethylene has the simplest structure and the highest ratio of hydrogen to carbon in its backbone. Most commercial polyethylene formulations also contain additives, such as stabilizers, antioxidants, crosslinking agents, slip and anti block agents, and fire retardants.

The molecular structure, molecular weight distribution and density will differ in various polyethylenes depending on the manufacturing process conditions. Low-density polyethylene (LDPE) is of low crystallinity (< 60%) and has a density in the range of 0.91-0.94 g cm^{-3} and a molecular weight of about 4 x 105 g mol^{-1}. High-density polyethylene (HDPE) is of high crystallinity ('"90%) and has a density in the range of 0.94-0.95 g cm^{-3} and a molecular weight up to about 3 x 106 g mol^{-1}. LDPE molecules are highly branched in structure and may contain up to 30 branches with as many as 10 carbon atoms each. HDPE molecules are almost linear in structure with only few short branches. HDPE is more thermostable than LDPE since secondary carbon hydrogen bonds are stronger than tertiary carbon hydrogen bonds[2,3].

Global annual production of plastics has doubled over the past 15 years, to 245 million tonnes in 2008[4]. They do not break down in the environment easily because they are resistant to microbial attack, due to their excessive molecular mass, high number of aromatic rings, unusual bonds, or halogen substitutions[5]. As a result they remain in the environment for a very long time without any deterioration and the large-scale accumulation of waste plastics in the biosphere has given rise to the problem of severe environmental pollution[6]. These problems have made plastic waste a major focus in the management of solid waste. Plastics exist in many different chemical compositions and are widespread in the society and the environment. The plastic polymers are not regarded as toxic, but there may be toxic residual chemicals, chemical additives and degradation products in the plastic products that can leach out as they are not bound to the plastic polymer.

Plastics

Plastic food and beverage containers became popular fairly recently (in the 1970s) and have become ubiquitous in our lives since then. Our food, it seems, is always touching plastic. Plastics play a part in every phase of food production and preparation. Food gets processed on plastic equipment, and packaged and shipped in plastic-lined boxes and cans. At home, we store and reheat the leftovers in plastic containers.

More than 30 types of plastics have been used as packaging materials including polyethylene, polypropylene, polycarbonates and polyvinyl chlorides[7]. Polyethylene and

polypropylene are the most common.

- **Polyethylene** plastic comes in high or low density. High-density polyethylene is stiff and strong and used for milk bottles, water and juice bottles, cereal box liners, margarine tubs, grocery, rubbish and retail bags but is not heat stable (i.e. it melts at a relatively low temperature). Low-density polyethylene is relatively transparent and used to make films of various sorts (including domestic/household cling film), and bread bags, freezer bags, flexible lids and squeezable food bottles.
- **Polyethylene terephthalate** (PET or PETE) is polyester. It is commonly used in soft drink bottles, jars and tubs, thermoformed trays and bags and snack wrappers because it is strong, heat resistant and resistant to gases and acidic foods. It can be transparent or opaque.
- **Polypropylene** is more heat resistant, harder, denser and more transparent than polyethylene so is used for heat-resistant microwavable packaging and sauce or salad dressing bottles.
- **Polycarbonate** is clear, heat resistant and durable and often used as a replacement for glass in items such as refillable water bottles and sterilisable baby bottles. It is also sometimes used in epoxy-based lacquers on the inside of food and drink cans to prevent the contents reacting with the metal of the can.
- **Polyvinyl chloride** (PVC) is heavy, stiff and transparent and often used with added plasticisers such as phthalates or adipates. Common uses of PVC with plasticisers include commercial-grade cling films for over-wrap of trays in supermarkets and filled rolls at delicatessens.

More and more research is proving that toxic compounds found in plastic cause health problems ranging from cancer to infertility. It is found that when the compounds that make up plastic are ingested, they damage your body on a cellular level and cause health problems. During the past five years, public awareness has slowly grown over concerns about compounds in some plastic bottles and food containers. The compounds on which most concerns have focused are Bisphenol A (known as BPA), which is used in tough polycarbonate products and epoxy resins that line tin cans, and a group of plastic softeners called phthalates.

Research has shown that these compounds can leach from plastics into the food and drinks that we consume - more so if they are heated to high temperatures, raising additional concerns about the kinds of plastics that are used as containers in microwave ovens.

To make plastics more useful, low molecular weight additives are used to increase flexibility, make them more 'sticky' (for cling film), heat stable or have anti-microbial compounds in them (for example). Small amounts of low molecular weight compounds may potentially leach into food during cooking or storage. From plastic bottles and some cans lined with polycarbonate-tiny amounts of bisphenol A are formed when polycarbonate bottles are washed with harsh detergents or bleach (e.g., sodium hypochlorite). Some food or drink cans may be lined with a lacquer to stop the food interacting with the tin. This may also release tiny amounts of bisphenol A. At high levels of exposure, bisphenol A is potentially hazardous because it mimics the female hormone estrogen. From commercial cling films made from PVC-DEHA: diethylhexyl adipate is a food-compatible phthalate plasticiser and tiny amounts may migrate into fatty food (such as meat or cheese), especially with heating. DEHP (diethylhexyl phthalate) is another plasticiser that has been of concern because it can migrate, and for that reason it is not used in food-related products in USA. It has been used as jar or bottle seals and lid inserts of bottles, spreads and juices and may be in printing ink for labels.

Additives such as antioxidants, ultraviolet (UV) stabilizers or plasticizers are necessary to protect packaging from UV, mechanical or oxidative deterioration or to increase softness or to improve the overall appearance or quality of the plastic product. The additives are not covalently bound to the polymer and are therefore susceptible to migration during heating or long term storage. Many of the chemical compounds that are common in commodity plastics have been compiled in legislative lists by the European union, and some compounds, with available toxicity data, have been assigned specific migration limit (SML) values for specified test conditions or worst case conditions, which must not be exceeded during the use of the packaging in order to be permitted in the EU market[8]. A large amount of different additives or other constituents of plastic packaging are, however, still not compiled into the lists and/or have unevaluated toxicity.

This is especially likely if the compounds are degradation products from additives or polymers. EU has also established regulations concerning the overall migration, which is the sum of all content that migrates from the polymer into the food or food stimulant without taking the identity of specific compounds into consideration. The overall migration is typically determined gravimetrically, by evaporating the food simulant and weighing the residue, after the migration tests. The overall migration limit (OML) that have been established for all types of plastics intended to be used in contact with food is 10 mg/dm^2, during standard storage conditions such as 10 days at 40°C or other worst case high temperature usage conditions depending on the package's intended usage.

Toxicity of plastics

Plastic polymers are not particularly reactive and their large size limits transport across biological membranes[9]. They are, therefore, not considered as toxic. In the plastic material, many non-polymeric components such as residual monomers, oligomers, low molecular weight fragments, catalyst remnants, polymerisation solvents and a wide range of additives can be present[10]. Some of these non-polymeric components are hazardous to human health and the environment, for instance carcinogenic, mutagenic, toxic for reproduction, sensitising and hazardous to the aquatic environment with long lasting effects. Since the non-polymeric compounds usually are of low molecular weight and are either weakly bound or not bound at all to the polymeric macro-molecules, they, or their degradation products, can be emitted from the plastic product[10,11] to air, water or other contact media (e.g. food). According to study of Jonas Alin, microwave heating of the packaged food and beverages may lead to migration of chemicals from food packaging to food[12].

One of the hazardous substance is brominated flame retardants used to retard ignition and prevent fire from spreading; some phthalate plasticizers mainly used to make PVC flexible; and lead heat stabilizers used to prevent degradation of PVC during processing[13]. Several polybrominated flame retardants are very persistent, very bioaccumulating and toxic, and are listed in the Stockholm Convention on Persistent Organic Pollutants (POPs)[14].

Another and one of the hazardous substance is BPA, which is a common synthetic chemical found in plastics, food cans linings, beverage can linings, baby bottles and other consumer products, which interferes with human hormones. BPA is capable of interfering with the action of estrogen, an important regulator of reproduction and development. Some of the developmental effects seen among rodents exposed to low doses of BPA include changes in brains and behaviors; precancerous lesions in the prostate and mammary glands; altered prostate and urinary tract development; and early onset of puberty (NTP Monograph on Bisphenol A).[15] As shown in studies, low-level exposure to BPA inhibits the release of adiponectin from human adipose (fat) tissue. Adiponectin increases insulin sensitivity and helps regulate glucose metabolism[16]. The researchers hypothesized that environmental BPA exposure may increase susceptibility to obesity and diabetes. In another study it is found that urinary BPA levels in humans were associated with increased prevalence of diabetes and cardiovascular disease[17]. Biedermann- Brem and Grob[18] systematically studied the effect of temperature on the release of BPA into tap water and boiled tap water of the same water supply by heating in a microwave for 5 min. The concentration of BPA in tap water increased from < 0.0001 mg/L at 50°C to 0.0006 mg/L at boiling temperature whereas

the concentration of BPA in boiled tap water having a pH of about 9.5 increased from < 0.002 mg/L at 50°C to 0.033 mg/L at boiling temperature.

One of the non-polymeric substances is phthalates, or phthalate esters, which are diesters of benzenedicarboxylic acid. Phthalates are used in wide variety of consumer products, including cosmetics, personal-care products, pharmaceuticals, medical devices, children's toys, food packaging, and cleaning and building materials. People may be exposed to phthalates through ingestion, inhalation, absorption through the skin, or parenteral administration. They have been linked to birth defects and are harmful to reproductive systems. Phthalates have been shown to cause a variety of effects in laboratory animals; however, their adverse effects on development of the reproductive system of male animals have led to particular concern. Those effects include infertility, decreased sperm count, cryptorchidism (undescended testes), hypospadias (malformation of the penis) and other reproductive tract defects and are referred to as the phthalate syndrome. In addition, the phthalate syndrome in animals has many similarities to a hypothesized syndrome in humans-testicular dysgenesis syndrome-although there are no human data that directly links the hypothesized syndrome in humans with phthalate exposure[19].

PVC or polyvinyl chloride plastic, commonly referred to as vinyl, gets its name "the poison plastic" because of the lifecycle of the plastic, which is toxic from start to finish. It is one of the most hazardous consumer products ever created. PVC is chlorine-based, so when it is manufactured or burned it results in the generation of dioxin, a known human carcinogen. It also contains 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. Organizations including the U.S.-based National Toxicology Program, the Environmental Protection Agency, the International Agency for Research on Cancer and the National Institute of Occupational Safety and Health agree that vinyl chloride monomer (VCM) is one of 52 chemicals/compounds designated as a confirmed human carcinogen.[20-22]

In another study, mudsnails cultivated in PET mineral bottles doubled their reproductive output, due to endocrine disruption, compared to those cultivated in Borosilicate Erlenmeyer flasks[23]. In a study by Olea et al.[24], saliva samples collected after

treatment with restorative dental filling composites (which are made from thermosetting acrylic composite bis-GMA) contained bisphenol-A and bisphenol-A dimethacrylate. The saliva samples were estrogenic in cell proliferation tests, compared to no estrogenicity in the saliva collected prior to filling.

In a study by Delilah Lithner[25], on *Daphnia magna,* showed acute toxicity of plastic monomers like ethylene oxide, vinyl chloride, propylene oxide, bisphenol A and benzyl butyl phthalate (BBP) had shown carcinogenicity, smutagenicity, specific target organ toxicity on repeated exposure, reproductive toxicity etc., while some of the monomers like propylene oxide, phenol, maleic anhydride have shown skin sensitization, reproductive toxicity, skin corrosion, sometimes acute toxicity.

CONCLUSION

Exposures to plastics, plasticizers, and other additives to polymers are ubiquitous in modern society. Of principal concern from a human health perspective are endocrine-disrupting properties of plastic components, such as BPA and DEHP. Another issue that may drive changes in production and consumption are the undesirable effects of plastics on the environment and wildlife. The quantity of plastics produced worldwide in the first decade of this century is equivalent to the total world production in the century prior. The need for changes in manufacturing and consumption patterns of plastics is both public health stand an ethical issue. Also, most plastic in the world is not recycled and usually ends up in landfills, where it degrades very slowly making the planet less habitable.

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