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Harmful Effects of Plastics on Human Health and the Environment: A Review

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ABSTRACT

Plastics play a ubiquitous role in our daily lives, and their absence would undoubtedly lead to a less diverse modern civilization. This research delves into the detrimental impacts of plastics on both human health and the environment, as well as the potential consequences of health risk assessment. Plastic, being an indispensable material for our modern society, often harbors risks to human well-being and the natural world. Within plastics lie numerous chemicals and toxic substances, such as Bisphenol A (BPA), phthalates, antioxidants, brominated flame retardants, and polyfluorinated chemicals, all of which pose significant hazards to human health and the environment. Unfortunately, people often utilize plastic without recognizing its adverse effects on their own well-being and the surrounding ecosystem. The consequences of plastic usage encompass a wide range of health issues, including eye irritation, vision problems, breathing difficulties, liver dysfunction, cancer, skin diseases, lung problems, headaches, dizziness, birth defects, reproductive disorders, cardiovascular ailments, genotoxicity, and toxicity to the digestive system. Moreover, plastics contribute to severe environmental pollution, such as soil, water, and air contamination. Implementing appropriate regulations and guidelines for the production and utilization of plastics can mitigate their detrimental impacts on human health and the environment.

KEYWORDS

Plastic; Bisphenol A; Phthalates; Pollution; Bangladesh.

1. INTRODUCTION

Plastic has revolutionized our daily lives, as we interact with plastic products in various ways. It plays a crucial role in enhancing our lives, being widely utilized across different sectors. Plastic simplifies and improves our lives by offering a multitude of benefits. Comprised of interconnected molecular monomers, plastics form macromolecules that serve infinite purposes in our society. Due to its inertness, durability, flexibility, and versatility, people are increasingly reliant on plastics. Although the durability and diverse applications of plastics, including disposable items, were foreseen, the challenges associated with waste management and plastic pollution were not anticipated (Yarsley& Couzens 1945). Plastic possesses unique properties, such as high heat combustion, low water content compared to biomass, minimal moisture absorption, and increased availability within local communities. Without plastic, our modern society would undoubtedly appear drastically different. Notably, plastic offers significant advantages in medical and public health applications. It is cost-effective, requires minimal energy for production, and is lightweight and biocompatible. Plastic can be soft, transparent, flexible, or biodegradable, serving as an innovative material for engineered tissues, absorbable sutures, prosthetics, and various medical uses (Andrady& Neal 2009). However, plastics also present several drawbacks, including the potential leakage of toxic substances that can harm humans and other organisms. Worldwide, approximately 20 types of prime plastics are utilized (APME 2006). Scientists have conducted a study that demonstrates the increased health risks associated with the long-term use of plastic bottles or containers. These containers often contain numerous chemical substances, many of which pose a serious threat to our well-being. For instance, chemicals like Bisphenol A (BPA), thalates, antiminitroxide, brominated flame retardants, and poly-fluorinated chemicals have been identified as potentially harmful (Halden 2010). BPA and phthalates can be found in various mass-produced items such as medical devices, food packaging, perfumes, cosmetics, toys, flooring materials, computers, and CDs, and can make up a significant portion of the plastic content. Phthalates, for example, can constitute a substantial proportion of PVC by weight, while BPA is used as a monomer in the production of polycarbonate plastics and as an additive in the production of PVC. Phthalates can leach out of products because they are not chemically bound to the plastic matrix, and their widespread use and high production volumes have attracted significant attention (Wagner &Oehlmann 2009). Phthalates and BPA have been detected in aquatic environments, dust, and even in the air due to their volatility (Rudel et al. 2001; 2003). The adverse effects of these chemicals on wildlife and humans have raised considerable concern (Meeker et al. 2009). The use and disposal of plastic should be a major concern for us. In 2007, the global production of polymers, including thermoplastics, thermoset plastics, adhesives, and coatings, but excluding synthetic fibers, was estimated to be around 260 million metric tons per year (Plastics Europe 2008). This indicates a historical growth rate of approximately 9 percent per annum. Thermoplastic resins account for about two-thirds of this production, and their usage is steadily increasing by about 5 percent worldwide.Approximately half of all plastics are utilized for disposable purposes, such as packaging, agricultural films, and disposable consumer items. Another 20 to 25 percent is allocated for long-term infrastructure, including pipes, cable coatings, and structural materials. The remaining portion is dedicated to durable consumer applications with intermediate lifespans, such as electronic goods, furniture, and vehicles. In 2007, the European Union (EU) generated 24.6 million tons of post-consumer plastic waste (Plastics Europe 2008). Over the period from 1989 to 2007, polymer imports increased from 10,000 tons to 289,000 tons per year. Currently, the total consumption of polymers, including imported polymers and recycled plastic waste, amounts to 750,000 tons in FY 2010-2011. This corresponds to a per capita plastic consumption of 5 kg per year in Bangladesh, which is significantly lower than the global average of 30 kg. In comparison, India and ASEAN countries have per capita consumption rates of 8 kg and 17 kg, respectively. While

Bangladesh was not well-acquainted with the various uses of plastics several decades ago, its major cities have witnessed a significant rise in plastic product usage in recent years. Consequently, Bangladesh is now grappling with the environmental, economic, and health issues caused by plastic pollution. In response to the environmental concerns, the government implemented a ban on poly bags. However, regrettably, polybags and other plastic products have gradually made a comeback in the market. Despite the current limited usage of plastic products, this is an opportune moment for policymakers to devise effective measures and for individuals to adopt environmentally friendly alternatives, such as natural fiber products. Delaying action will only make it more challenging to change people's habits in the future.

2. CATEGORIES OF PLASTICS

2.1. Type 1 polyethylene terephthalate or PET plastic: Polyethylene terephthalate, commonly known as PET plastic, is primarily utilized in the production of disposable water bottles. Additionally, it is employed in the manufacturing of various utensils and containers used for storing juices, soft drinks, butter, salad dressings, vegetable oil, mouthwash, cosmetics, and more. PET plastic is characterized by its thin, transparent, and smooth texture. Due to its liquid-tight and anti-inflammatory properties, it is highly favored for packaging water and other food items. Its airtight nature prevents the entry of oxygen, ensuring that the contents of the bottles remain uncontaminated. Moreover, liquids or beverages are not easily washed away from the interior of PET bottles. It is worth noting that type 1 plastic bottles do not contain harmful bacteria or phthalates, but they may contain antimony trioxide. Antimony is considered a potential carcinogen when present in the human body. Prolonged contact with drinking water can lead to the release of antimony from the container. Research has shown that exposure to high temperatures can also cause toxic levels of antimony to leach from PET bottles. Therefore, it is crucial to keep these bottles away from elevated temperatures. It is important to mention that type 1 or PET plastic is intended for single-use only. In terms of safety, PET bottles are relatively safe for one-time use.

2.2. Type 2 High-density polyethylene: High-density polyethylene (HDPE) is the most widely used plastic globally. It is derived from petroleum and is known for its heat-resistant properties. Type 2 plastic, which is made from HDPE, is commonly employed in the production of milk containers, detergent bottles, refrigerators, toys, various types of plastic grocery bags, and more. HDPE is relatively strong, durable, and resistant to heat. It does not contain harmful substances such as BPA or phthalates, making it a safe choice for various applications. However, studies have indicated that prolonged exposure to sunlight can cause the release of nanalifenal from type 2 plastic due to ultraviolet rays.Compared to type 1 container, type 2 containers are considered to be safer for food and drink.

2.3 Type 3 plastic containers, on the other hand, are used for fruit juice, cooking oil, and other similar products: on the level of plasticization, type 3 plastic can be flexible and unobtrusive. However, it is important to note that the use of phthalates to make PVC flexible can be harmful to the human body. PVC pipes and siding also contain phthalates. PVC itself contains many toxic chemical substances such as BPA, phthalates, lead, dioxin, crater, and cadmium. The entire life cycle of PVC, from production to disposal, is associated with severe health risks and environmental pollution, which has led to a significant reduction in its use. Despite this, PVC remains popular in consumer products due to its cost-effectiveness and versatility. However, it is important to be aware of the poisonous nature of PVC and its potential to cause various health issues such as cancer, birth defects, genetic changes, chronic bronchitis, ulcers, skin diseases, deafness, vision failure, indigestion, and liver dysfunction.

2.4 .Type 4 plastic, known as low-density polyethylene, is a heat-resistant polymer made from petroleum. It can be both transparent and opaque. Type 4 plastic containers are commonly used in the packaging of frozen foods and the preparation of juices and milk cartons. There is no risk of harmful components leaching into the container or the bottled fluid. Therefore, the use of type 4 plastic containers is safe for food and beverages.

2.5. Type 5 plastic, known as polypropylene, is a strong and semi-transparent plastic polymer. It is known for its strength, high heat resistance, and hydrophobic properties. Type 5 plastic is commonly used for packaging yogurt, medicine, beverages, ketchup, and other similar products. It is important to note that no harmful substances are found in food or water that comes into contact with polypropylene plastic.Most polypropylene plastic is safe for use in the microwave and dishwasher, as it does not cause any harm. Similar to type 4 plastic, polypropylene containers are considered safe for storing food and beverages.

2.6. Type 6 polystyrene is a petroleum-based plastic that is prepared using benzene, a known carcinogen. Polystyrene is commonly used in packaging materials and insulation, but it poses health risks due to the presence of styrene. Prolonged exposure to styrene has been linked to neurotoxic, hematological, cytogenetic, and carcinogenic effects. The International Agency for Research on Cancer (IARC) has classified styrene as a human carcinogen.

2.7. Type 7 plastics, except for the specific type mentioned, are labeled as type 7 plastics. Polycarbonate containers, which fall under type 7, are made with BPA. When food or beverages are stored in these containers, the BPA can be released. Multiple studies have proven the health risks associated with BPA, leading to a significant decrease in the use of type 7 or polycarbonate plastic. While polycarbonate is commonly used for packaging consumer goods, its use in baby bottles and reusable bottles (3 and 5 gallons) is considered unsafe due to the health risks associated with type 7 or polycarbonate plastic.

3. EFFECTS OF PLASTIC ON HUMAN HEALTH

Plastics pose potential risks to human health due to their monomeric building blocks, additives, or a combination of both. These include substances like Bisphenol A (BPA) and plasticizers. BPA is commonly used as a building block in polycarbonate plastics and as an additive in other plastics like polyvinyl chloride (PVC). It has been in use since 1891 and is produced in large quantities worldwide. A significant amount of BPA comes into contact with food, as it can be released from beverage and food containers over time. This leaching process is accelerated by repeated washing of containers and when storing acidic or basic items that break down the polymer. Consequently, reusable water bottles, baby bottles, and the inner linings of food cans, all made with BPA, are known to release this controversial substance into food, especially at higher temperatures. Studies have shown that food and drinks stored in such containers, including the popular clear water bottles often seen hanging from hikers' backpacks, may contain trace amounts of BPA. These trace amounts can potentially interfere with the body's natural hormonal messaging system, as BPA is considered a hormone mimic of reproductive hormones like estrogen. The main sources of exposure to BPA in the human body are through food consumption and inhalation.Various studies have discovered that BPA is linked to numerous health issues, including ovarian chromosomal damage, decreased sperm production, rapid puberty, rapid changes in the immune system, type-2 diabetes, cardiovascular disorders, and obesity, among others. Additionally, some studies have suggested that BPA increases the risk of breast cancer, prostate cancer, pains, and metabolic disorders. In women, BPA has been associated with impaired health, such as obesity, endometrial hyperplasia, recurrent miscarriages, sterility, and polycystic ovarian syndrome (Warner et al., 2002; Rayner et al., 2004; Eskenazi et al., 2007). The levels of

unconjugated BPA in human blood and tissues range from 0.1 to 10 µg/L in the human body and are assessed in blood serum and urine (Ikezuki et al., 2002; Schonfelder et al., 2002). The determination of BPA is done through enzyme-linked immune sorbent assay (ELISA). The geometric means for daily intake of BPA, estimated from urinary levels, are higher in males than females (53.8 versus 41 ng/kg/day) and higher in children and adolescents (64.6 and 71 ng/kg/day, respectively) compared to adults. The exposure levels in adults decrease with age, from 52.9 ng/kg/day in 20–39-year-olds to 33.5 ng/kg/day in seniors aged 60 years and older (Lakind& Naiman, 2008). The elevated exposure of women of childbearing age and children is particularly concerning due to the known vulnerability windows to BPA, which put the developing fetus and children at a higher risk compared to adults exposed to the same levels of the contaminant (Vandenberg et al., 2009). The U.S. EPA determined a reference dose for humans at 50 µg per kg per day by applying a safety factor to account for extrapolation from animals to humans, variability in the human population, and extrapolation from sub-chronic to chronic exposures (Welshons et al., 2003).

The reference dose for BPA was determined based on the lowest observable adverse effect level (LOAL), as adverse responses were observed even at the lowest tested dose (Vandenberg et al. 2009). Current concerns regarding BPA primarily stem from the low-dose effects observed in human populations and the recognition that biologically active levels of BPA detected in human blood are within or above the concentrations known to cause changes in human tissue function in vitro (Vom& Hughes 2005). Phthalates, which are diesters of phthalic acid, have been produced in large quantities since the 1930s. The properties of phthalates depend on the length and branching of the dialkyl or alkyl/aryl side chains, i.e., the alcohol component of the ester. Di (2-ethylhexyl) phthalate (DEHP), produced annually in quantities of 2 million tons and widely used in medical devices, is an example of a phthalate. Major routes of human exposure to phthalates include medical exposures resulting from the direct release of phthalates into the human body (e.g., through dialysis, blood transfusions, and extracorporeal membrane oxygenation [ECMO]), as well as ingestion of contaminated materials such as food and house dust (Sathyanarayana 2008; Kamrin 2009; Meeker et al. 2009). Phthalates typically function to enhance the flexibility of plastics, such as polyvinyl chloride (PVC). Similar to BPA, phthalates can cause hormonal imbalances, disrupting normal hormone function and daily activities. Both BPA and phthalates can enter the body of newborns through pregnancy and breastfeeding, posing potential harm. However, it is important to note that phthalates are slightly less harmful to humans compared to BPA. Therefore, it is crucial to be aware that various plastic containers may contain harmful levels of both BPA and phthalates.

4. EFFECTS OF PLASTIC ON THE ENVIRONMENT

The distribution of plastic debris varies greatly due to several factors, such as wind and ocean currents, urban areas, and trade routes. Additionally, the human population in certain areas significantly contributes to this issue. Plastic debris can also serve as carriers for chemical contaminants, including persistent organic pollutants and heavy metals (Barnes et al. 2009). The negative environmental impact of plastics is further exacerbated by the release of toxic chemicals during their manufacturing process. Carcinogenic, neurotoxic, and hormone-disrupting chemicals are commonly found in plastic production, and they inevitably contaminate our environment through water, land, and air pollution. Some well-known compounds include vinyl chloride (in PVC), dioxins (in PVC), benzene (in polystyrene), phthalates and other plasticizers (in PVC and other plastics), formaldehyde, and Bisphenol-A, or BPA (in polycarbonate). Many of these chemicals are persistent organic pollutants (POPs), known for their high levels of toxicity and long-lasting presence in the environment. Their uncontrolled release into the environment negatively impacts both terrestrial and aquatic life. The manufacturing process in plastic industries also emits a significant amount of

hazardous gaseous chemicals, such as carbon monoxide, dioxin, and hydrogen cyanide, which heavily pollute the air. The presence of these gases in high proportions poses a threat to the health of both humans and animals, potentially leading to respiratory diseases, nervous system disorders, and weakened immune systems. Furthermore, chlorinated plastic can release harmful chemicals into the surrounding soil, which can then contaminate groundwater and other water sources, posing a serious threat to species that rely on these water sources.Landfill areas are home to a variety of plastic materials. Within these landfills, numerous microorganisms exist that accelerate the process of plastic biodegradation. These microorganisms consist of bacteria such as Pseudomonas, nylon-eating bacteria, and Flavobacteria. Through the action of the enzyme nylonase, these bacteria break down nylon. The breakdown of biodegradable plastics results in the release of methane, a potent greenhouse gas that significantly contributes to global warming (Biello 2013). Additionally, some scientists propose that the presence of floating polymer fragments in the oceans could contribute to global warming by creating a shaded canopy that inhibits plankton growth. It is crucial to recognize that the plant kingdom serves as the universal carbon sink. The issue of water pollution caused by plastic waste is a grave concern. Frequently, we dispose of discarded plastic products in various water bodies, including lakes, rivers, and ponds. The lakes in the bustling city of Dhaka serve as a prime example of pollution caused by plastic bottles, canes, bags, and other plastic items frequently discarded by visitors. The presence of plastic waste in water bodies disrupts the natural flow, hampers fish reproduction, and destroys beneficial organisms.

5. ANSWERABLE ORGANIZATIONS AND RULES FOR REDUCING PLASTIC TOXICITY

The government is currently facing a significant challenge in effectively managing plastics. In order to address concerns regarding human health and environmental pollution, numerous rules and regulations have been established and enforced in both developing and developed countries to regulate the production and usage of plastic materials. Various Indian organizations and agencies, such as the Ministry of Environment and Forest, Ministry of Health, and Mobile court, bear the responsibility of ensuring the sustainable production, usage, and disposal of plastic and plastic materials. Bangladesh took the lead in banning plastic bags to combat environmental pollution, and even after more than a decade, many developed countries are still struggling to replicate this accomplishment. If it is scientifically proven that plastic bags or products made from polyethylene or polypropylene are harmful to the environment, the government has the authority to regulate or prohibit their usage in specific areas or throughout the entire country.

6. CONCLUSIONS

Plastic toxicity is a widespread problem that affects nature at various levels. Research has shown that exposure to toxic chemicals used in plastic production has harmful effects on human health and the environment. Unfortunately, many people unknowingly use these toxic plastics. The detrimental impact of plastics on human health and the environment 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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