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Review Article

Critical Review on Bisphenol A: Invisible Pollution

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A R T I C L E I N F O

A B S T R A C T

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BisphenolA (BPA) has become ubiquitous in the environment within the past 80 years because of its presence in every plastic material. Therefore, the present review article has been critically designed after reviewing numerous original research papers on BPA, to understand the presence of BPA in different spheres of environment viz. biosphere, lithosphere, hydrosphere and atmosphere. The omnipresent chemical has been measured in human blood, urine and umbilical cord blood and thus confirms its presence in biosphere. Recently, much attention has focused and revealed air to the growing list of places where BPA is found, said by Japanese researchers who have measured and reported levels of the chemical in the world's atmosphere. Moreover, researchers found that BPA floats in the air attached to particles that can infiltrate lungs. Recycling these plastics, cans and receipts, may be good for reducing energy and trash, but it also seems to be putting BPA into hydrosphere. Many studies have since quantified BPA levels in various aqueous media, including fresh and marine surface waters, treatment plant influents and effluents, and groundwater. The primary source of BPA in soils is the land-application of sewage sludge or biosolids in this way it contaminates soil also. It has also opened a new expanse of research with a need to have continuous monitoring and elimination of evil effects of BPA and its exchange between in environment. This will help in formulation of strategies which will monitor the levels of BPA in environment and decrease the level of BPA pollution.

Key words: Bisphenol A, environmental pollution, water, soil, air

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1. INTRODUCTION

Climate change is recently one of the most important issues in environmental sciences. Many scientific groups are concerned about worldwide temperature and precipitation changes within near future. However, not only rising temperatures and increase of natural disaster are able to modify regions, nutrients, animal or human populations but also environmental pollution in surface water. Since few years especially xenobiotica and recently pharmaceutical compounds are objects of ecotoxicological studies. Xenobiotica contain to the group of “endocrine disruptors” (ED). EDs are compounds which interfere with endocrine systems and disrupt their normal functions within an organism without remarkable toxicity. Since the 1990`s an increasing pollution of such compounds was noticed for instance in surface waters, agricultural areas, and atmosphere, especially since the analytical methods for detection have been continuously improved.

Many of the thousands of anthropogenic chemicals currently released into the environment are endocrine-disrupting compounds (EDCs). These are defined as exogenous chemicals or chemical mixtures that impact endocrine system structure or function and cause adverse effects. Endocrine systems regulate a multitude of developmental, metabolic, and reproductive processes including embryonic development, gonadal formation, sex differentiation, growth, and digestion. Endocrine-disrupting compounds may affect these processes by either binding to or blocking hormone receptors, thereby triggering or preventing hormonal response. Chemicals implicated in endocrine disruption include biocides, industrial compounds, surfactants, and plasticizers including bisphenol A.

BisphenolA (BPA) is monomer of polycarbonate plastics and epoxy resins. BPA has become ubiquitous in the environment within the past 80 years because of its presence in a multitude of products including food and beverage packaging, flame retardants, adhesives, building materials, electronic components, and paper coatings[1]. As demand for these products has increased, so has BPA production. By 2003, global production of BPA was 3.2 million metric tons [2]. Global consumption of BPA in 2011 was predicted to exceed 5.5 million metric tons [3].So, it is very clear that there will be confidentrise in the use of BPA progressively in forthcoming years.

Bisphenol A is a pseudo-persistent chemical, which despite its short half-life is universal in the environment because of continuous release[4]. Release can occur during chemical manufacture, transport, and processing. Post-consumer releases are primarily via effluent discharge from municipal wastewater treatment plants, leaching from landfills, combustion of domestic waste, and the natural breakdown of plastics in the environment. Formed by the condensation of phenol with acetone(Fig. 1), BPA has a low vapor pressure, high melting point and moderate solubility[5]. Based on reported log KOW values that range from 2.20 to 4.16[6], BPA is considered to have low or moderate [7-8] hydrophobicity and thus a modest capacity for bioaccumulation. Based on these various characteristics, it is estimated that the largest environmental compartments of BPA are abiotic and are associated with water and suspended solids (w53%), soil (w25%), or sediments (w23%) [9].

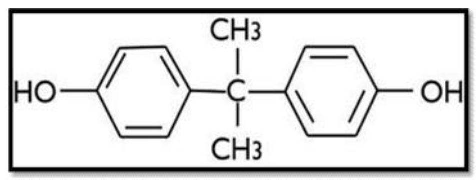

Fig 1: Structure of Bisphenol

BPA can migrate into foods from cans and from polycarbonate plastic products such as baby bottles, tableware, and food containers. The use of BPA in food and beverage containers accounts for the majority of daily human exposure; estimated human consumption of BPA from epoxy-lined food cans alone was 6.6 μg/person-day[10]. Warming the plastic, such as in a microwave, increases the leaching of BPA into liquids; temperature appears to be a more important factor in leaching than the age of the container.

So, this review article abridges that BPA is an infamous environmental contaminant which pollutes atmosphere, hydrosphere and lithosphere in circular modus. Furthermore, it also creates menace to human health. Therefore, it had also unwrapped a different area of exploration with a great prerequisite to have continuous monitoring and elimination of malicious effects of BPA and its exchange between in environment. This will help in formulation of strategies which will monitor the levels of BPA in environment and decrease the level of BPA pollution

2. BPA CONTAMINATES WATER

The primary route of BPA contamination in the aquatic environment is effluent from wastewater treatment plants and landfill sites.Observed BPA concentrations in oceans and estuaries are relatively low compared to some freshwater systems. However, BPA leaching could be a concern at marine sites where plastic waste has accumulated, as BPA leaches more rapidly in marine than in freshwater systems[11]. In addition, the bioavailable fraction of dissolved BPA may increase with salinity [12].

3. BPA CONTAMINATES SEDIMENTS AND SOILS

Studies in which bothwater and sediments were sampled report much higher BPA concentrations in the sediments than in the upper water column. Funakoshi and Kasuya[13]noted a strong correlation between BPA levels near the base of the water column and those in the sediment, which is consistent with observations of slow BPA biodegradation in anaerobic environments. With reported log KOC values ranging from 2.50 to 4.5 [14], BPA is thought to have a moderate affinity for soil organic matter and is therefore unlikely to be mobile or bioavailable in soils. Loffredo and Senesi[14]documentedrapid and complete desorption of BPA in sandy, acidic soils. The primary source of BPA in soils is the land-application of sewage sludge or biosolids[15]. Reported levels of BPA in biosolids vary by many orders of magnitude, ranging from 0.10 to 3.2 ×107 mg/kg dry weight [16]. The half-life of BPA in soils has been estimated as 3 days, 7 days, and 37.5 days. No degradation was observed in anaerobic soils after 70 days[17] or in anoxic estuarine sediments after 120 days[18]. Bisphenol A presence in soils may constitute a significant concern.As an environmental contaminant, BPA interferes with nitrogen fixation at the roots of leguminous plants associated with thebacterial symbiont *Sinorhizobiummeliloti*. Despite a half-life in the soil of only 1–10 days, its ubiquity makes it an important pollutant.

4. BPA CONTAMINATES AIR

The atmosphere is a geochemical reservoir of various organic compounds, interacting with the oceans, land, and living organisms including human beings. One important environmental issue is the origin, transport and fate of organic pollutants in atmospheric aerosols and their health effects with responses to human exposure being both acute and chronic[19]. Although its volatility is lower than that ofwater, BPAcan be released into the atmosphere via industrial production with a rate of some 100 t year^{-1}. In addition, BPA could be emitted from the combustion of computer printed circuit boards in electronic waste (e-waste) and from the spraying of paint [20].

A study by Fu and Kawamura [21] had shown the presence of BPA in atmospheric aerosols collected at different geographical locations in the world (Fig. 1). The concentration ranges of BPA are summarized in Table 1. The highest level of BPA was observed in PM_{10}aerosols from Chennai and Mumbai, India. In Chennai,the concentration range was 200-17,400 pgm^{-3} (average 4550 pgm^{-3}). A detailed analysis of the organic molecular compositions of the Chennai aerosols suggests that the open burning of municipal wastes including plastics was very active in Chennai, especially during night time. Chennai aerosols suggest that the open burning of domestic plastic wastes could be a significant emission source of atmospheric BPA inthis region. Also, they explained that the atmospheric levels of BPA in Indian megacities are roughly one order of magnitude higher than those in China, Japansuggesting that the human exposure of BPA in South Asia is more serious than other regions.

In the marine aerosols collected during a round-the-world cruise of R/V Hakuho, the highest level of BPA was observed off the coast of the Asian continent (Fig. 1). The general decrease of BPA from the Asian coastal region to the central North Pacific Ocean indicates that the Asian continent is a strong "emitter" of BPA, which can be transported long distances by the westerly winds with terrestrial higher plant biomarkers, showed that the marine aerosols over the western North Pacific during winter/spring were transported from the Asian continent under the influence of westerly winds [22].

The polar atmosphere was once believed to be extremely clean. In 1950s, pilots flying over the North American Arctic observed a widespread Arctic haze. Arctic haze is a mixture of sulfate, ammonium, nitrate, black carbon, and particulate organic matter including persistent organic pollutants. In the Arctic aerosols collected at Alert (82^{o}300N, 62^{o}180W) in 1991, the levels of BPA ranged from 1to 11 pgm^{-3} with higher concentrations in the dark winter than in the early summer. This pattern suggests that BPA can be transported from the mid-latitudes in Eurasia and North America to the Arctic, because the Arctic can act as a cold sink during winter to receive the aerosols and their precursors via long-range atmospheric transport[23].

5. BPA CONTAMINATES WILDLIFE

At concentrations ranging from 1.1 to 12.8 mg/L, BPA is systemically toxic to various taxa, including daphnids, mysids, and both freshwater (Pimephalespromelas) and saltwater (Menidiamenidia) fishes (Alexander et al., 1988). Based on reported EC50 and LC50 values that range from 1.0 to 10 mg/L[9], BPA is classified as "moderately toxic" and "toxic" to aquatic biota by the European Commission and the United States Environmental Protection Agency (US EPA), respectively [24]. However, studies of BPA effects on wildlife indicate that the compound may be harmful even at environmentally relevant concentrations, which are defined as 12 mg/L or lower [25].

6. BPA AND HUMAN HEALTH

It is clear that BPA is capable of interfering with the action of estrogen, an important regulator of reproduction and development. (Interference with hormonal action is often referred to as *endocrine disruption*.) Therefore, many recent studies have focused on the potential effects of low levels of BPA exposure on fetal or newborn rats or mice. 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. Other tests have shown that bisphenol A can promote human breast cancer cell growth, decrease sperm counts in rats, and cause erectile dysfunction and other sexual problems in men.

Table 1: Detailed information on the aerosol samples and BPA concentrations (pgm^{-3}) (Fu and Kawamura, 2010)

Aerosol sample				Concentration		Reference
Location	**Sampling time**	**Type**	**Number**	**Range**	**Average**	
Urban site						
Chennai, India	Winter & Summer, 2007	PM_{10}	49	200-17,400	4550	Fu & Kawamura,2010
Mumbai, India	Winter & Summer, 2008	PM_{10}	24	100-9820	2480	Fu & Kawamura,2010
Beijing, China	August, 2007	$PM_{2.5}$	10	380-1260	630	Fu & Kawamura, 2010
Oska, Japan	Oct.2000-March 2001	$PM_{2.5}$	36	10-1920	510	Matasumo et al., 2005
Marine region						
Indian ocean	Feb, 1990	TSP	1	-	6	Fu & Kawamura, 2010
North Pacific region	Nov, 1989	TSP	4	1-2	2	Fu & Kawamura, 2010
Polar region						
Alert, Canadian High Arctic	Feb.-June 1991	TSP	16	1-11	5	Fu & Kawamura, 2010

Some researchers have proposed that BPA may interfere with functions other than reproduction and development, potentially causing additional types of health effects. The body of research in this area is less extensive than that into BPA's potential effects on reproductive hormones, but this appears to be an area of active investigation. For example, a recently published study found that low-level exposure to BPA inhibits the release of adiponectin from human adipose (fat) tissue. Adiponectin increases insulin sensitivity and helps regulate glucose metabolism. The researchers hypothesized that environmental BPA exposure may increase susceptibility to obesity and diabetes. Another study found that urinary BPA levels in humans were associated with increased prevalence of diabetes and cardiovascular disease. Investigators called for long-term studies to determine whether high BPA levels are associated with specific health effects later on, an approach that would provide stronger evidence, one way or the other, regarding a possible causal role of BPA on adverse health effects.

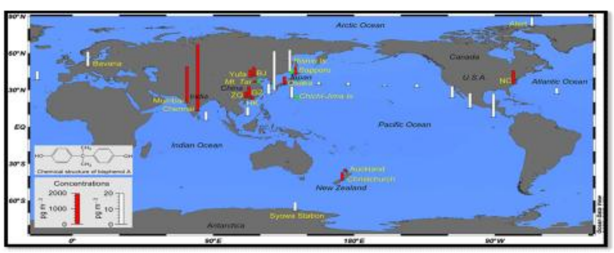

Fig. 2 Spatial distributions of the mean concentrations of BPA in atmospheric aerosols collected at different locations in the world. Urban and rural sites are presentedin red, while marine and remote sites including the polar regions are in white, (Fu and Kawamura, 2010)

7. CONCLUSIONS

The growing problem of EDC release into the environment requires the development of technologies able to minimize or eliminate adverse environmental exposures. Certain defensive measures should be framed for the culmination of the effects of BPA to pollute environment i.e .atmosphere, lithosphere and hydrosphere as well as biosphere. 1,3,5-triphenylbenzene can be used as specific tracer for open burning of plastics, especially when coupled with the presence of the antioxidant tris(2,4-di-tert-butyl-phenyl) phosphate (TBPP). Another possible removal process is the photodegradation of BPA during long-range atmospheric transport. The photooxidation products could be phenol, 4-isopropylphenol, and asemiquinone derivative of BPA. Since BPA has the potential to cause undesirable ecological and human health effects, various treatment technologies have been developed for its removal from water. The oxidative degradation methods for BPA such as ozonation, photo-Fenton reaction, photocatalytic reaction by TiO2 and ultrasound-UV-iron(II) treatment can be used for removal of BPA from water. Thus, if ill effects of BPA are eliminated from water, soil and air then it would be very stress-free biosphere.

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