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Review

Sensors and biosensors for analysis of bisphenol-A

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ABSTRACT

We discuss state-of-the-art sensing methods for the detection of bisphenol-A (BPA), a well-known and much studied contaminant causing a wide range of health problems to living beings especially the young. These methods are rapid, sensitive, inexpensive and suitable for on-site monitoring. We comprehensively review the principles, the mechanisms and the performances of chemical sensors and biosensors available in the literature. We also discuss future perspectives in developing sensors for the detection of BPA.

Contents

Abbreviations: BPA, Bisphenol-A; PC, Polycarbonate; EDC, Endocrine disrupting compound; MIPs, Molecularly imprinted polymers; CNT, Carbon Nanotube; MWCNTs, Multi-walled carbon nanotube; SWCNTs, Single-walled carbon nanotubes; CoTe, Cobalt-Tellurium; PAMAM, Polyamidoamine; rGO, Reduced graphene oxide; SELEX, Systemic evolution of ligands by exponential enrichment; BHPVA, 4,4-Bis(4-hydroxyphenyl)valeric acid; ELISA, Enzyme-linked immunosorbent assay; HRP, Horse radish peroxidase; SPR, Surface-plasmon resonance; MAbs, Monoclonal antibodies; PAbs, Polyclonal antibodies.

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1. Introduction

Bisphenol A (BPA) is scientifically known as 4,4′-(propane-2, 2-diyl)diphenol. It is used as a monomer in the synthesis of polycarbonate (PC) and epoxy resins (Fig. 1a). It also finds application in the synthesis of polyacrylate, polysulfonate, unsaturated polyester resins and flame retardants. BPA is one of the most important chemicals synthesized globally in high volumes and is in high demand. A wide variety of food-storage or packaging materials are produced from PC, such as feeding bottles, water bottles and cans, tableware and microwave ovenware. Epoxy resins are also used as an internal coating material for lacquered cans and bottles used for the processed foods. BPA is a ubiquitous, well-known food-packaging migrant and contaminant, which raises concerns about food safety. BPA leaches into food products from the packaging material due to thermal treatment in processing (Fig. 1a) [1,2]. Apart from food-contact materials, it also finds many applications {e.g., production of currency notes, thermal printing paper, compact disks, adhesives, and powder paints [3,4]}. Recently, Geens et al. [3] reviewed the possible sources of BPA exposure to human beings. It is present in a wide array of food and other items and pollutes the biotic and abiotic environments [5]. The exposure estimate for populations, primarily through food intake, is in the general range 0.1–1.5 μg/kg body weight/day. It is roughly estimated that more than 2000 tonnes of BPA and its products are released into the environment annually due to domestic and industrial activities [6].

BPA is a potent endocrine-disrupting compound (EDC) and its toxicity is widely reported in literature [7]. The structure of BPA is analogous to endocrine hormones, namely estradiol and diethylstilbestrol, due to the presence of phenol groups in their structure [8] (Fig. 1b), so it has affinity to bind estrogen receptors. It has been demonstrated that low doses, even at sub-ng levels (0.23 ng/L) can affect human health [9]. Exposure to BPA is well known as affecting the functions of brain, thyroid, ovary and reproductive organs [10,11]. Generally conjugated forms of BPA (e.g., BPA-glucuronide, BPA-disulfate and BPA-chlorides) are found in biological samples [12]. Enhanced BPA levels in the urine of adults have led to increased incidence of sexual dysfunction in men. BPA is associated with cardiovascular diseases, obesity, carcinogenicity, neurotoxicity and developmental problems [13,14]. It also causes wheezing

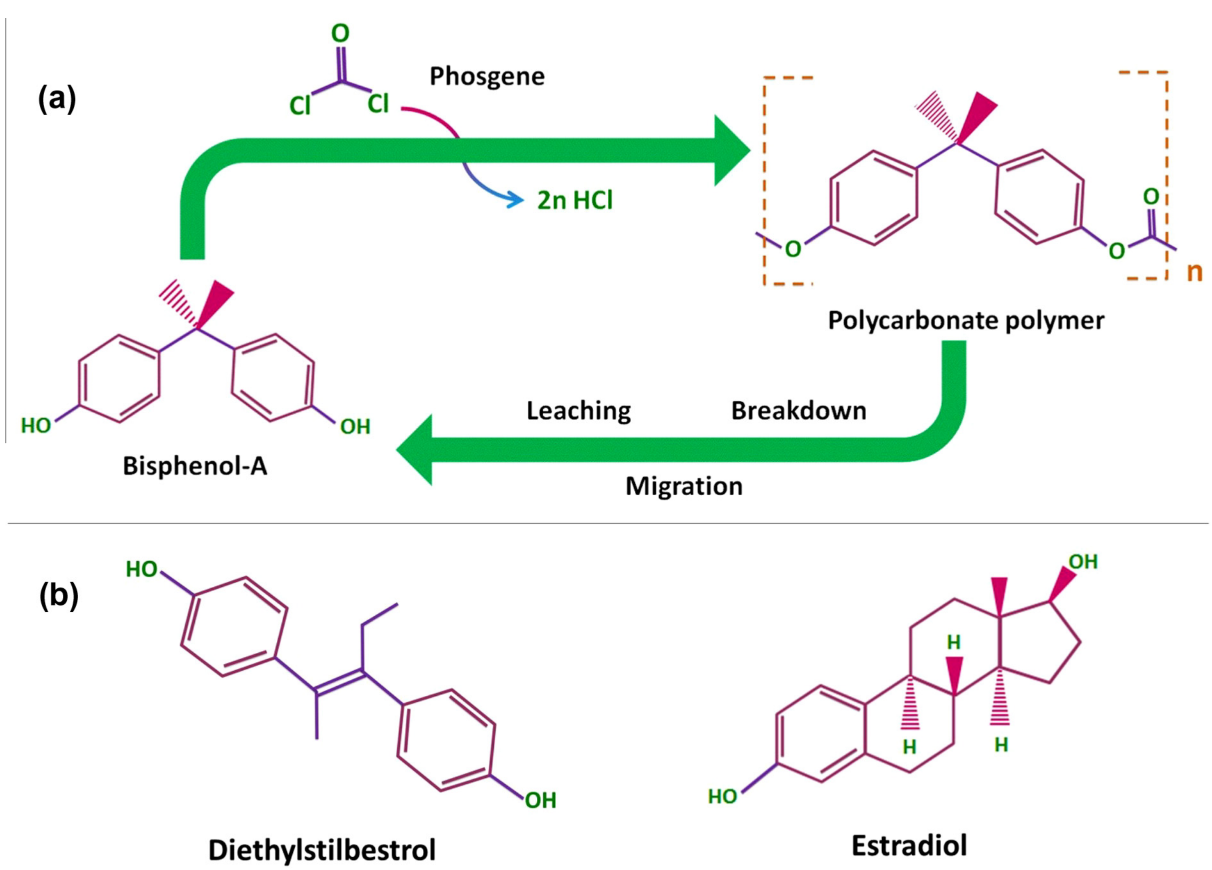

Fig. 1. (a) Synthesis of polycarbonate polymer from bisphenol-A and its breakdown to bisphenol-A. (b) Hormones structurally analogous to bisphenol-A.