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Review

Advances in sensing and biosensing of bisphenols: A review

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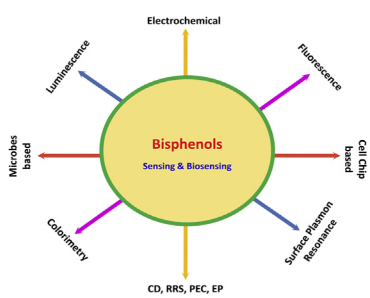
HIGHLIGHTS

- Bisphenols are major environmental contaminants and endocrine disruptors.
- State of the art of sensing and biosensing approaches for Bisphenols (BPs) detection.
- Varied nanomaterials and bioreceptors based sensors employed for BPs analysis.
- Sensing strategies for screening of BP analogs other than BPA are not many.

GRAPHICAL ABSTRACT



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ABSTRACT

Bisphenols (BPs) are well known endocrine disrupting chemicals (EDCs) that cause adverse effects on the environment, biotic life and human health. BPs have been studied extensively because of an increasing concern for the safety of the environment and for human health. They are major raw materials for manufacturing polycarbonates, thermal papers and epoxy resins and are considered hazardous environmental contaminants. A vast array of sensors and biosensors have been developed for the sensitive screening of BPs based on carbon nanomaterials (carbon nanotubes, fullerenes, graphene and graphene oxide), quantum dots, metal and metal oxide nanocomposites, polymer nanocomposites, metal organic frameworks, ionic liquids and molecularly imprinted polymers. This review is devoted mainly to a variety of sensitive, selective and reliable sensing and biosensing methods for the detection of BPs using electrochemistry, fluorescence, colorimetry, surface plasmon resonance, luminescence, ELISAs, circular dichroism, resonance Rayleigh scattering and adsorption techniques in plastic products, food samples, food packaging, industrial wastes, pharmaceutical products, human body fluids and many other matrices. It summarizes the advances in sensing and biosensing methods for the detection of BPs since 2010. Furthermore, the article discusses challenges and future perspectives in the development of novel sensing methods for the detection of BP analogs.

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1. Introduction . . . 2
2. Sensing and biosensing of bisphenols in different matrices . . . 2
2.1. Electrochemical sensors and biosensors . . . 3
2.1.1. Nanomaterials based sensors . . . 3
2.1.2. Ionic liquids based sensors . . . 12
2.2. Fluorescence based sensors . . . 13
2.3. Chemiluminescence based sensors . . . 13
2.4. Colorimetric sensors . . . 14
2.5. Surface plasmon resonance sensors . . . 14
2.6. Some significant sensing platforms . . . 14
2.6.1. Microorganisms based sensors . . . 14
2.6.2. Cell chip based sensors . . . 16
2.6.3. Other significant sensors . . . 16
3. Conclusion, challenges and future perspectives . . . 17
Notes . . . 20
Acknowledgements . . . 20
Abbreviations . . . 20
References . . . 22

1. Introduction

The presence of hormone disruptors in the environment and in various common consumer goods is an area of concern for human health and biosafety. Endocrine disruptors (EDCs) block the metabolism of steroid hormones, as they possess significant potential for altering the structure and function of the endocrine system. Consequently, exposure to EDCs results in a number of disorders related to obesity, diabetes, cardiovascular diseases, carcinogenicity and neurotoxicity [1]. Bisphenols (BPs) are well-known endocrine disrupting compounds that contain two hydroxyphenyl groups, and there are more than fifteen BP analogs. The chemical structures of various BPs are summarized in Table 1. With the extensive evidence of adverse effects of BPs on human health and the environment, numerous studies have been performed to assess their toxicity [2]. Various worldwide regulatory bodies and health agencies have reported on various risk assessment studies on bisphenols [3–5].

Bisphenol A (BPA), 2, 2-bis (4-hydroxyphenyl) propane, is a very popular member of the BP family that has potent endocrine-disrupting activity [6]. In addition, BPA has diverse industrial applications as a raw material for manufacturing a wide variety of food storage and packaging materials, water pipes, bottle tops, tableware and microwave ovenware [6,7]. Routine procedures involving heating and hydrolysis during Pasteurization, canning, microwave heating, sterilization and washing of the vessels result in increased leaching of BPA into food products, raising concerns for food safety [8]. Many studies have been reported on the exposure of BPA to human and biotic life, and discuss adverse outcomes such as the destruction of basic physiological processes and widespread environmental contamination [9,10].

Apart from BPA, bisphenol B (BPB, 2,2-bis (4-hydroxyphenyl) butane) [11,12], bisphenol S (BPS, 4,4′-dihydroxy diphenyl sulphone) [13], bisphenol AF (BPAF, 1,1,1,3,3,3-hexafluoro-2,2-bis (4-hydroxyphenyl) propane) [14,15] and bisphenol F (BPF, 4, 4′-dihydroxydiphenyl-methane) [16] are other members of the bisphenol family that are prominent endocrine disrupters that came to attention after the onset of strict regulations on the production and usage of BPA [17]. Furthermore, tetrabromo bisphenol A (TBBPA, 2, 2′, 6, 6′-tetrabromo-4, 4′-isopropylidenediphenol), is one of the widely used BPs and is produced by reacting bromine with BPA. It is used as a brominated flame retardant during the manufacturing of electronic appliances [18,19]. Having a structural similarity to thyroxin, it exhibits a strong affinity towards transthyretin [20–22]. In addition, bisphenol AP (BPAP, 1,1-bis(4-hydroxyphenyl)-1-phenyl-ethane), bisphenol E (BPE, 1,1-bis(4-hydroxyphenyl) ethane), tetrachlorobisphenol A (TCBPA, 2,2′,6,6′-tetrachloro-4,4′-isopropylidenediphenol) and bisphenol Z (BPZ, 1,1-bis(4-hydroxyphenyl)-cyclohexane) are other members of the bisphenol family that have attracted considerable attention due to their adverse chemical properties [23].

Various analytical procedures have been reported for the routine determination of BPs. Recent developments in the field of materials chemistry offer new possibilities for novel sensor designs based on advance functional nanostructures [24]. Recent trends in the construction of stable and robust sensors based on different nanomaterials and bio-recognition elements such as aptamers, enzymes, antibodies and whole cell have been discussed widely for monitoring environmental toxins [23,25]. Analytical methods for the detection of BPs are generally based on various chromatographic [26] and hyphenated methods, such as gas chromatography-mass spectrometry (GC-MS) [27]. However, sensing and biosensing methods have taken a different course recently toward much more sensitive, selective and convenient detection techniques having comparatively low cost, high accuracy and enhanced user compatibility. Recently, a large number of electrochemical processes have been reported that emphasize the catalytic oxidation of BPs. In addition, other sensing strategies based on colorimetry, fluorescence, luminescence, optical and immune sensing techniques have been proposed for the detection of BPs in diverse sample compositions. Newly developed methodologies for the detection of BPs have been validated by analytical procedures (e.g., HPLC/GC) for judging the quality, reliability and consistency of analytical results in terms of specificity, precision, reproducibility, stability and recovery.

The present article summarizes advancements since 2010 in the development of various sensors and biosensors for the sensitive detection of bisphenols in different matrices based on electrochemical, fluorescence, luminescence, colorimetry, surface plasmon resonance and other techniques. The developed sensors have been categorized according to their method for detecting BPs.

2. Sensing and biosensing of bisphenols in different matrices

Various strategies have been developed for sensing and biosensing BPs in different media based on the chemical