HIBISCUS PUBLISHER

BULLETIN OF ENVIRONMENTAL SCIENCE AND MANAGEMENT

WEBSITE: http://journal.hibiscuspublisher.com/index.php/BESM

Mini Review: Electrochemical Sensor for the Detection of Bisphenol A (BPA)

Sinniah Subathra[1]*, Baskaran Gunasekaran[2]

[1]Department of Chemistry, Faculty of Science, University of Malaya, 50603 Kuala Lumpur, Malaysia
[2]Department of Biochemistry, Faculty of Biotechnology and Biomolecular Sciences, Universiti Putra Malaysia, UPM 43400 Serdang, Selangor, Malaysia

***Corresponding author:** suba2887@gmail.com
Department of Chemistry, Faculty of Science,
University of Malaya, 50603 Kuala Lumpur, Malaysia

HISTORY
Received: 3rd of October 2014
Received in revised form: 27th of November 2014
Accepted: 25th of December 2014

KEYWORDS
bisphenol a
electrochemical sensor
mini review

ABSTRACT

Bisphenol A is one of the highest produced chemical in the world, which have been used broadly in many industries and commercial applications. It is widely used in production of polycarbonate and epoxy resins. Worldwide production of BPA is growing rapidly and expected to reach 5.4 million tonnes by 2015. However, past research has shown that BPA exhibits potential hazards to both human and the environment and this is becoming a major concern in many countries. In this mini review, we have focused on recent studies on electrochemical sensors to detect BPA. Various type of electrochemical sensor have been successfully developed with good sensitivity and responses.

INTRODUCTION

Food security has been identified as one of the major issues in global food supply chain. As the global food supply becoming increasingly important, attention towards food safety and quality also equally increased. Food contaminations could occur due to human errors, environment factors or even due to terrorism attack. Thus, a sensitive and accurate analytical tool is needed to monitor real time food born contamination event and provide safety guarantee for consumers.

Bisphenol A (BPA) is an organic molecule with two phenol moieties, which also known as 2, 2-bis (4-hydroxyphenyl) propane and 4, 4′-isopropyllidenediphenol [1]. BPA is grayish or colorless crystalline powder or granule with chlorophenol like odor. It is synthesized by condensation of phenol with acetone in the presence of strong acid ion-exchange resin as a catalyst. The chemical structure of BPA is as shown in Fig 1.

$$(CH_3)_2CO + 2\ C_6H_5OH \rightarrow (CH_3)_2C\ (C_6H_4OH)_2 + H_2O$$

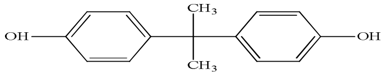

Fig 1. Bisphenol A.

BPA is an estrogenic substance which is widely employed as a key building chemical monomer in the manufacturing of multitude chemical products [2]. Polycarbonate (PC) and epoxy resins are two types of major plastics that are produced by using BPA. Other minor usage of BPA including in production of polyester-styrene, polycarbonate resins, flame retardants, dental monomers, medical equipment and tubing, and consumer electronics [3]. BPA consist of two derivatives, bisphenol A diglycide ether (BADGE) and bisphenol F diglycide ether (BFDGE), which also have industrial importance [4].

However, BPA is a type of endocrine disturbing chemicals (EDC) which mimic estrogen activities and lead to adverse effect for both human beings and animals [5, 6]. These EDC disturbances potentially cause cancerous tumor, development disorders, birth defects, reduce immune functions, decrease semen quality and weaken reproduction [7, 8]. Several reports have highlighted that BPA in the environment originated from migration of PC tools or containers and epoxy coating. Studies have shown that when the plastics are heated or frequently exposed to dishwasher and microwave, the BPA will leach out faster than normal conditions [9].

Analysis of BPA

Many analytical methods have been designed for the detection of BPA such as liquid chromatography (HPLC) [10], liquid chromatography coupled with mass spectrometry (LC-MS) [11], gas chromatography (GC), gas chromatography coupled with mass spectrometry (GC-MS) [12] and enzyme linked immunosorbent assays (ELISA) [13]. However, these techniques are relatively not sensitive, complicated, time consuming and expensive. Therefore, electrochemical analysis has drawn many researchers' attentions due to its quick response, cheap instruments, sensitive, selective and simple. In this review, the efficiency of accurate response and different electrode material that have been developed for BPA detection, have been highlighted.

Electrochemical study on BPA

Yu *et al*, [14] reported the application of chitosan-Fe_3O_4 (CS-Fe_3O_4) nanocomposite for the determination of BPA. To evaluate the response of the CS–Fe3O4/GCE, the proposed method was used to detect BPA in different plastic samples under optimized conditions. Under the optimized conditions, the oxidation peak current was proportional to BPA concentration in the range between 5.0×10^{-8} and 3.0×10^{-5} mol dm^{-3} with the correlation coefficient of 0.9992 and the limit of detection of 8.0×10^{-9} M. The modified glass carbon electrodes (GCE) were successfully employed to determine BPA in real plastics with recoveries from 92.0% to 106.2%. The low detection limit and good stability showed a promising amperometric determination of BPA.

Masikini *et al*, [15] has investigated on amperometric sensor for the endocrine disruptor-BPA using hydroxyl-iron/β-cyclodextrin-film (FeOx-βCD). The composite was drop coated on the surface of glass carbon electrode (GCE) and the electrochemical oxidation and detection of BPA were studied. The modified GCE sensor was successfully demonstrated using "Stoney Ginger Beer samples" spiked with saturated BPA solution with 100% recovery rate. The FeOx-βCD/GCE was very useful voltammetry sensor in selected real sample matrix without interference from the components of the sample.

Yin *et al*, [16] described the development of simple and sensitive electroanayltical method for determination of BPA in milk using poly (amidoamine) (PAMAM) and Fe_3O_4 nanoparticles modified GCE. Under optimum condition, the oxidation current increased linearly with increasing the concentration of BPA in the range of 1×10^{-8}– 3.07×10^{-6} M with the correlation coefficient of 0.9996 and the detection limit of 5×10^{-9} M. The practical application demonstrated using milk sample with recovery rate from 95.3% to 104%. The method proposed showed high determination sensitivity, easy preparation process and low cost.

Meanwhile, Fan *et al*, [17] used nitrogen-doped grapheme sheet (N-GS) and chitosan (CS) to prepare electrochemical BPA sensor. The sensor showed sensitive response towards the endocrine disruptor in the range of 1.0×10^{-8} – 1.3-× 10^{-6} mol L^{-1} with a low detection limit of 5.0×10^{-9} M under optimized conditions. Determinations of BPA were employed using water samples. The suggested method gave a satisfactory result with recoveries from 95.8% to 106.5%. A sensitive and reliable electrochemical method was successfully proposed. Xu *et al*, [18] applied a new carbon based material, carbon nanohorns (CNHs) to produce a reliable electrochemical method for determination of BPA. The proposed technique (CNHS/Nafion/GCE) demonstrated a remarkable oxidation signal increasing linearly with increasing concentration of BPA in the range of 2.0 x 10^{-6} - 1.0 x 10^{-3} mol L^{-1} and detection limit of 1.8 x 10^{-6} M. The results indicated a strong catalytic oxidation activity towards BPA where an excellent sensitive sensor and quantitatively reproducible analytical performance were produced.

In 2013, Zhang *et al,* [19] developed a sensitive and robust method for measurement of BPA. The method was based on magnetic nanoparticles decorated reduced grapheme oxide (rGO) composites and chitoson (MNPs-rGO). Under optimal experiment conditions, the oxidation peak current was proportional to the concentration of BPA in the range if 6.0 x 10^{-8} to 1.1 x 10^{-5} mol L^{-1} with detection limit of 1.7 x 10^{-8} M. Electrochemical sensor based on MNPs-rGO showed outstanding stability, reproducibility and selectivity. The method was successfully applied for the determination of BPA using different kind of plastic products with satisfactory recovery over the range from 97% to 109.2%.

Liu & Zhang [20] developed a rapid and sensitive electrochemical sensor based on silica and nanocomposite prepared from reduced graphene oxide and gold nanoparticles (SiO2/rGO–AuNPs). The modified GCE electrochemical sensor obviously reduced the oxidation over potential of BPA compare to bare GCE. Under optimal conditions, the oxidation current peak response towards BPA concentration within the range of 1.0 x 10^{-5} to 1.2 x 10^{-4} mol L^{-1} with low detection limit of 5.0 x 10^{-9} M. This simple, accurate, sensitive and selective analytical method was successfully designed with thermal paper samples with recovery range from 96.39% to 108.3%.

Table 1. Summary of electrochemical sensor for BPA detection.

Sensor	Range of Linearity (μM)	R value	Detection Limit (M)	Reference
CS-Fe_3O_4	0.5-30	0.9992	8.0×10^{-9}	[14]
FeOx-βCD	0.1-50	0.998	5×10^{-7}	[15]
PAMAM-Fe_3O_4	0.1-3.07	0.9996	5×10^{-9}	[16]
CS/N-GS	0.1-1.3	0.9996	5.0×10^{-9}	[17]
CNHS/Nafion	2.0-1000	0.996	1.8 x 10^{-6}	[18]
MNPs-rGO/CS	0.06-11	0.9977	1.7 x 10^{-8}	[19]
SiO2/rGO–AuNPs	1-120	0.9927	5.0 x 10^{-9}	[20]

CONCLUSION

BPA has high potential for adverse effect on human health and environment. It is crucial to develop simple and effective methods for detection of BPA. This review has discuss on recent develop electrochemical sensor for BPA. Various studies have been carrying out in developing excellent sensing system. Fabrication of sensors has been accommodating in designing an ideal sensor. Owning the outstanding feasibility, the electrochemical sensor method shows outstanding advantages such as quick, rapid response, high sensitivity, accurate analysis and low cost. The practical application also demonstrates satisfactory recovery. Therefore, the electrochemical method can be proposed for on-side measurement of BPA with simple and low cost preparation. However, for widespread acceptance, further validation of the sensor capability is needed to ensure the precision in BPA quantification.

REFERENCES

[1] Huang YQ, Wong CKC, Zheng JS, Bouwman H, Barra R, Wahlström B, Neretin L, Wong MH. Bisphenol A (BPA) in China: A review of sources, environmental levels, and potential human health impacts. Environ. Int. 2012; 42:91-9.

[2] Dash C, Marcus M, Terry PD. Bisphenol A: Do recent studies of health effects among humans inform the long-standing debate? Mutat. Res-Rev Mutat. Res. 2006; 613:68-75.

[3] Mutou Y, Ibuki Y, Terao Y, Kojima S, Goto R. Chemical change of chlorinated bisphenol A by ultraviolet irradiation and cytotoxicity of their products on Jurkat cells. Environ. Toxicol.Pharmacol. 2006; 21:283-9.

[4] Rykowska I, Wasiak W. Properties, threats, and methods of analysis of bisphenol A and its derivatives. Acta Chromatogr. 2006; 16:7.

[5] Bredhult C, Sahlin L, Olovsson M. Gene expression analysis of human endometrial endothelial cells exposed to Bisphenol A. Reprod. Toxicol. 2009; 28:18-25.

[6] Huang J, Zhang X, Liu S, Lin Q, He X, Xing X, Wenjing L. Electrochemical sensor for bisphenol A detection based on molecularly imprinted polymers and gold nanoparticles. J. Appl. Electrochem. 2011; 41:1323-8.

[7] Vandenberg LN, Maffini MV, Sonnenschein C, Rubin BS, Soto AM. Bisphenol-A and the great divide: a review of controversies in the field of endocrine disruption. Endocr. Rev. 2009; 30:75-95.

[8] Vom Saal FS, Cooke PS, Buchanan DL, Palanza P, Thayer KA, Nagel SC et al. A physiologically based approach to the study of bisphenol A and other estrogenic chemicals on the size of reproductive organs, daily sperm production, and behavior. Toxicol. Ind. Health. 1998;14(1-2):239-60.

[9] Brede C, Fjeldal P, Skjevrak I, Herikstad H. Increased migration levels of bisphenol A from polycarbonate baby bottles after dishwashing, boiling and brushing. Food Addit. Contam. 2003; 20:684-9.

[10] Kuroda N, Kinoshita Y, Sun Y, Wada M, Kishikawa N, Nakashima K, Tsunehisa M, Hiroyuki N. Measurement of bisphenol A levels in human blood serum and ascitic fluid by HPLC using a fluorescent labeling reagent. J. Pharma. Biomed. Anal. 2003; 30:1743-9.

[11] Chen M, Edlow AG, Lin T, Smith NA, McElrath TF, Lu C. Determination of bisphenol-A levels in human amniotic fluid samples by liquid chromatography coupled with mass spectrometry. J. Sep. Sci. 2011; 34:1648-55.

[12] Chang C-M, Chou C-C, Lee M-R. Determining leaching of bisphenol A from plastic containers by solid-phase microextraction and gas chromatography–mass spectrometry. Anal. Chim. Acta. 2005; 539:41-7.

[13] Ballesteros-Gomez A, Rubio S, Perez-Bendito D. Analytical methods for the determination of bisphenol A in food. J. Chromatogr. A. 2009; 1216:449-69.

[14] Li J, Lin Y, Liu X, Zhang Q, Miao H, Zhang T, Bangcai W. The study of transition on NiFe2O4 nanoparticles prepared by co-precipitation/calcination. Phase Transit. 2011; 84:49-57.

[15] Masikini M, Waryo TT, Baker PG, Ngqongwa LV, Williams AR, Iwuoha EI. Hydroxy-Iron/β-cyclodextrin-Film Amperometric Sensor for the Endocrine Disruptor Substance Bisphenol-A in an Aqueous Medium with Reduced Fouling Effects. Anal. Lett. 2011; 44:2047-60.

[16] Yin H, Cui L, Chen Q, Shi W, Ai S, Zhu L, Linan L. Amperometric determination of bisphenol A in milk using PAMAM–Fe_3O_4 modified glassy carbon electrode. Food Chem. 2011; 12:1097-103.

[17] Fan H, Li Y., Wu D, Ma H, Mao K, Fan D, Bin D, He L, Qin W. Electrochemical bisphenol A sensor based on N-doped graphene sheets. Anal. Chim. Acta. 2012; 711:24-8.

[18] Xu G, Gong L, Dai H, Li X, Zhang S, Lu S, Yanyu L, Jinghua C, Yuejin T, Guonan G. Electrochemical bisphenol A sensor based on carbon nanohorns. Anal. Methods. 2013; 5:3328-33.

[19] Zhang Y, Cheng Y, Zhou Y, Li B, Gu W, Shi X, Yuezhong X. Electrochemical sensor for bisphenol A based on magnetic nanoparticles decorated reduced graphene oxide. Talanta. 2013; 107:211-8.

[20] Liu E, Zhang X. Electrochemical sensor for endocrine disruptor bisphenol A based on a glassy carbon electrode modified with silica and nanocomposite prepared from reduced graphene oxide and gold nanoparticles. Anal. Methods. 2014; 6:8604-12.